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ART. L.—*Valley of the Minnesota River and of the Mississippi River to the junction of the Ohio: its origin considered;* by Gen. G. K. WARREN, Major of Engineers. With Diagrams A, B, C, C′, D, E, F and G (making plates 11 to 18 of the volume).

Definition of the term "valley," prominent natural features and length.—The *valley* to be considered is the part included between the high banks, commonly called bluffs. Whenever it becomes necessary in this article to refer to the whole area drained by the river, the word *basin* will be used to designate it.

Between these high banks the greater portion is subject to overflow at time of floods, forming what is sometimes called the *flood plain;* the smaller part above overflow is generally composed of alluvial terraces of sand and gravel. In some cases the distinction between the terraces and the bluffs is difficult to make.

The Mississippi River in its usually navigated parts touches only here and there at places exempt from flood-waters, and these are natural landings for steamboats and sites for towns. In course of time the convenience of the people living there makes them desirable locations for bridges. It is very rare, however, that both banks of the river are above submergence; where one bank is, the opposite one is generally low, and covered many feet deep at extreme high-water, making it difficult to construct bridges sufficiently elevated for steamboats to pass under them.

The distance along the general course of this valley from St. Louis to St. Paul is about 620 miles, but steamboatmen, by the course they take along the navigable channels, make the distance

about 800 miles. This was the only part specified in the law authorizing this investigation, but it was necessary in order to present the subject itself properly to include the whole distance from the mouth of the Minnesota to the Ohio; this is an extent of about 760 miles along the general course of this valley, and we have prepared a map of it in twenty-two sheets on a scale of two inches to a mile. The manner in which this is done is described in Chapter VI of this report.

General map and profile prepared for publication.—Although we have, in constructing the map, exhausted all means of obtaining knowledge in regard to this part of the Mississippi Valley, there are some parts of it too little determined to make its publication as a whole, advisable, and therefore we have only prepared for publication the index map of those twenty-two sheets, on a scale of six miles to an inch. (If photo-lithographed it may vary from this scale.) Here, again, generalizations have led us to make this index map include the Minnesota River Valley. That valley, under another clause of the law, was also made a part of my investigation, and a map in twenty sheets on a scale of two inches to the mile was made for it. The map submitted for publication is also an index map to those Minnesota Valley sheets now on file at Engineer headquarters in Washington. We have also extended this general map southward so as to include overflowed land as far as the northern part of Arkansas, and northward to include a part of the basin of the Red River of the North. It is designated as Diagram 1, in five sheets.

The two systems of the United States land surveys, one on each side of the river, are so checked upon each other in its construction and by special surveys by ourselves, that the valley on this small scale is probably as correct as it can be represented. The whole of the flood-plain is shaded with light ruled lines, except the principal lakes and water-courses, which are shaded with heavy lines. The alluvial terraces above overflow are shaded with dots. The high banks or bluffs are without shading. On sheet five there are some overflowed lands that are above the Mississippi floods, which have special shading.

In order to complete a presentation of the Mississippi flood-plain to the Gulf of Mexico, the page Diagram A is added, reduced from Plate II of the report of Humphreys and Abbot on the physics and hydraulics of the Mississippi.

General considerations as to the formation of the Mississippi Valley have caused me to present also the page Diagram B, showing the Mississippi basin as it is, and extending northward to include the Lake Winnepeg basin with the ancient extension of the lake southward and outflow through the valley of the Minnesota and Mississippi Rivers.

Profiles prepared for publication.—Accompanying this chapter are two sheets of longitudinal profiles of the valley from the junction of the Minnesota River to the junction of the Ohio. The horizontal scale is about eight miles to an inch, and the vertical 200 feet to an inch, reduced in publication. The datum is the sea-level according to the best determinations, and both sides of the valley are given side by side. The parts of the banks above low-water are shaded to indicate the strata of different geological periods, but it must be borne in mind that this low-water line does not represent the low-water slope of the winding river, but is drawn from point to point along the general course of the valley, so as to bring the rocks into their proper relative positions. These longitudinal profiles are designated as Diagram 2, in two sheets.

Another sheet, designated as Diagram 3, gives twenty transverse valley sections, on a larger scale than the profiles: three of them on the Minnesota Valley; one on the Mississippi, above the junction with the Minnesota; fourteen of them in the valley between the Minnesota and the Ohio; one at the mouth of the Missouri River, and one at the mouth of the Illinois River. These sections are designed to show the extent of our positive knowledge of the depth of the bed-rock, and will be described in detail in the latter part of this chapter.

We are mainly indebted for the geological data in these profiles and sections to the report of David Dale Owen, October, 1851, on the Geological Survey of Wisconsin, Iowa and Minnesota; to the report on the Geological Survey of Iowa, by Prof. James Hall, Prof. J. D. Whitney and Mr. A. H. Worthen, published in 1858, and the report of Mr. A. H. Worthen, director of the Geological Survey of Illinois, published in 1866.

Method of treating question of depth of bed-rock.—The question of depth of the bed-rock beneath the sand that usually forms the bed of the river will occupy the remainder of this chapter.

In presenting my ideas in regard to it, I have thought the best order in which I could arrange them would be that in which they arose in the progress of the investigation. It was from the first obvious that means and time would not allow of my covering such an extended field by actual borings, and that the most that could be done was to draw such probable inferences as could be done by a study of the rocks visible in the bluffs and by an effort to comprehend the manner in which the valley was formed.

The consideration of the anomaly presented by Lake Pepin lying in the course of the river, and said to have a depth of sixty feet near its lower end, was the beginning of this effort. If the valley in this portion had once been all of this depth, and since filled in, then the bed-rock could not be less than sixty feet

below the water surface. Explanations of the cause of this lake had been attempted by Long and by Featherstonhaugh, which did not seem to me satisfactory.

Explanation of the cause of Lake Pepin and similar lakes.—The results of the levelings on the Minnesota and Mississippi Rivers made by me showed that just below the entrance of any considerable affluent there was an accumulation of deposit in the main stream brought by the tributary; that over this deposit the slope of the water was greater than the average slope, and that it was shoal and impeded navigation; that just above the affluent the slope was less than the average, and the water deeper. So far, this was in accordance with conditions which generally exist in rivers, and might be so even where the main stream was gradually wearing away and deepening its bed.

But a marked peculiarity was exhibited at the junction of the Minnesota and Mississippi Rivers. Regarding the Mississippi as the affluent (which we might do from the comparative sizes of the two valleys), the rule here would be as it is elsewhere, steep slope and shoal water below the affluent and almost no slope and very deep water above. In this instance the effect is felt above for at least thirty miles. On the other hand, taking the Mississippi as the main stream (as the volume of its water has always caused it to be regarded), then we have the anomaly of the main stream filling up the valley and damming back the affluent so that the latter brings no coarse material whatever into the main valley or has any part in forming the shoal below the junction of the two streams.

I called attention to this in my report published in 1867, and again made the anomalous condition a feature in my report on the Minnesota River,* where diagrams were given of the streams and valleys at the junction, and of the Minnesota at its source in Lakes Big-Stone and Travers, which I here repeat as Diagrams C and C′. The Minnesota Valley maintains these widths and depths throughout its course. I have also prepared a small contour map of the sources of the Minnesota and Mississippi Rivers, to show the important position occupied in this system of slopes by the Minnesota Rivers, and give it as Diagram G.

In the report on the Minnesota, above referred to, I showed that the valley of the Minnesota River had, in the period subsequent to the glacial-drift epoch, been occupied by a much larger river, which had formed the outlet of a great lake, embracing the lake Winnipeg and receiving the drainage of its basin, and extending as far south as the present Lake Traverse at the sources of the Minnesota River.† This ancient river, if its volume were as great in proportion to area as that of the

* Annual Report Chief of Engineers, 1875, Part I, page 387.
† Ibid, 1868, pp. 307–314.

Mississippi above the Falls of St. Anthony, probably equaled Niagara in volume, and would have been sufficient to prevent the formation of such excessive accumulation of *débris* in its course, such as the Mississippi is now making below the Minnesota River, although it is probable that the material brought into it from the near proximity of the Falls of St. Anthony would have had the usual effect of somewhat increasing the slope and shoalness just below its junction, and decreasing the slope and increasing the average depth just above.

Accepting, then, the conclusion which I have elsewhere made reasonable, that the drainage of the Winnipeg basin was formerly along the Minnesota and Mississippi below the junction, then when the flow of water from that great northern basin ceased there would no longer be the volume of water necessary to remove the deposits brought by the affluents into a channel of too great capacity for the requirements of the new conditions.

In building the railroad bridge across the mouth of the Minnesota, Mr. Shepard, the engineer, made borings to ascertain the character of the foundations. A rod was forced down about sixty feet, at which distance a stratum was reached so yielding that the rod's weight would be barely supported. He did not endeavor to probe further, for just before reaching this soft layer he passed through a harder one of sufficient thickness and resistance to support his structure. This bridge is a work of minor character. This shows that the deposit in the old valley exceeds sixty feet at this point. The Minnesota being a muddy stream, its fine silt has much filled the lake which the Mississippi *débris* at its mouth caused.

The *débris* and material brought over and from the Falls of St. Anthony has been carried downward by the water, gradually accumulating and filling the valley as it advanced. One should here stop and consider the manner in which river deposits are made. The finest clay is so easily mingled with the water, that the slightest disturbances in the fluid as it moves along even with gentle currents, is sufficient to keep it from settling down until still water is reached. The amount of this on the Upper Mississippi is comparatively very small. Such materials as can be moved only by the swiftest currents are rolled over along the bottom, gradually diminishing in size by friction, and furnishing smaller particles susceptible of being thus moved by feebler currents. The resulting material is pebbles, gravel and sand, the fine material such as clay and vegetable matter, being all washed out.

When deposits of gravel or sand are made of materials moved along the bottom, it takes place as soon as the current slackens, as it must do on reaching a place having a larger sectional area. The deposit is sudden, and the material is all taken up in diminishing the section, until the velocity of transportation is

restored; then deposition continues immediately in front of the last deposit. Such deposition, therefore, does not extend laterally from the course of the current into any contiguous dead water, as depositions from water holding a clayey or vegetable matter would.

Thus in the valley of the Mississippi, the lakes alongside the river's course are deeper than the river, which has continued to raise its bed by deposits of sand after the lakes were cut off from its current.

From the Falls of St. Anthony down to the St. Croix River the Mississippi Valley receives no considerable tributary. The St. Croix comes from a region of trap rock now furnishing little or no large and heavy sedimentary matter. The result has been that the Mississippi deposit of sand and gravel has been thrown across its mouth, holding back its water and forming the St. Croix Lake. At low water, while the depth of the Mississippi at the junction is two and one-half feet. the depth in Lake St. Croix is twenty-five feet. It is not probable that twenty-five feet depth represents the amount of filling of the ancient valley at this point, because the lake itself must have been somewhat shoaled with fine deposits of clay and vegetable matter.

The next considerable tributary to the Mississippi Valley is the Chippewa River. This, entering at right angles with a steep river slope and a probable high-water volume of at least 40,000 cubic feet per second, comes from a region inexhaustibly supplied with siliceous sand and gravel containing a considerable of the heavy magnetic sand, whose oxidation often cements the other sand deposits.* It brings quantities of these materials which, spread out below, give a very steep slope to the Mississippi River, and very bad shoals for navigation.

Lying just above this deposit is Lake Pepin, which it completely accounts for. The reason this lake has not been filled up by the Mississippi above is that the supply of sand from the Chippewa is so great as to raise the level more rapidly than the filling above can keep pace with. The Chippewa from the left bank pushes its sand-bar out, so as to confine the outlet of the lake to the opposite shore. There is an observable relation between the condition of the lake and the deposits of the Chippewa. The deepening of the waters by the deposit of Chippewa sands is felt at low water sometimes as far up as the mouth of the St. Croix, when floods in the Chippewa make these deposits large, and on the other hand, in times of droughts the waters of the lake cut the outlet deeper, and lower its level, so that the shoal water is moved down the river two to three miles below the St. Croix.

* "The analysis of the soil on this part of the Chippewa River (the Yellow Banks) gives ninety-three per cent of insoluble matter, which is chiefly white sand, with only two per cent of organic matter, less than four per cent of soluble saline matter, consisting chiefly of oxide of iron and alumina with only a trace of calcareous earth."—Owen's Report, p. 56.

If we follow the Mississippi down we find similar conditions produced by the Wisconsin River as by the Chippewa; that is, a great increase of the slope and shoaling of the river below the junction, with gentler slopes, deep water, and lake-like aspect above. There would probably have been a large lake here, if the affluents above had not silted it up.

Another instance is afforded by the damming-back effect of the Mississippi deposit at the mouth of the Illinois River, making it at low water almost like a lake up to La Salle.

Lake Pepin must therefore be regarded as due to the deposit by the Chippewa of heavy coarse sediment into the valley of an ancient and larger river. This view may be strengthened further by the following considerations: It lies immediately in the course of the main valley above an important tributary. In this respect it agrees with Lac-qui-parle, on the Minnesota, just above the Lac-qui parle River; with another lake on the same valley just above Yellow Earth River; with Big Stone Lake in the same valley, just above Whetstone River; with Lake Traverse, which is formed by deposits from a stream at each end, and thus empties sometimes in both directions. It agrees in this relation with the lakes on the Qu'Appelle, which all lie just above a considerable tributary, and with like lakes on the Upper Fox of Lake Winnebago. This constant relation seems unmistakably one of cause and effect.

Valley now filling up.—From what has been stated above, it is clear that the river valley in the part we have considered is not now being deepened by erosions, but, on the contrary, is filling up, and it appears to be doing so all along its lower course except at the rapids.

Recent drainage of Lake Winnipeg southward.—As I have stated in previous reports, I regard the ancient river draining the Winnipeg southward by the Minnesota and Mississippi Valley as existing subsequent to the glacial deposits. This is based upon the fact that the river's course is cut through those deposits, as shown by the banks in many places from Lake Traverse, in Minnesota, to Warsaw, in Illinois, and that the ancient bed of Lake Winnipeg is free from glacial deposits, and exhibits only the silt-deposit since made by the ancient lake itself.

Valley formed since the glaciers began to retire.—It also seems most probable that the ancient valley itself, as a whole, was formed in the region of glacial deposits, partly during the period this great field of ice was receding, and partly since it left the ancient Mississippi basin, for the following reasons: When this ice-period was on the increase, its southern margin must have been gradually advancing in this region, crushing down and planing off the ridges and filling the ravines and water-courses with the *débris* not only of the neighboring rocks, but with

the great mass of hard rocks and other material brought from regions far to the north. There seems a probability that much of the present Upper Mississippi basin had previously been for long ages exposed only to erosions of streams and of the atmosphere, so that it was probably much cut up and fissured, as we see in regions farther west, where no glacial action has occurred. It must have been an easy matter then for the glacier to have thoroughly filled up all the valleys and ravines, leaving the surface everywhere of the well-known rounded hill and basin forms of the drift regions. Wherever the glacial scratchings are preserved, their uniform directions indicate a massive movement to the southwest quite independent of all influence of underlying inequalities. The water which flowed from them would seek the first lowest line and excavate its course without regard to the nature of the older stratified rocks buried beneath the glacial deposits, and such seems to have been the case, for the valley takes a great variety of courses, running about northeast at St. Paul, due west at Rock Island, and its directions fill every azimuth in different parts from northeast around by south to west. To the old stratified rocks its course seems to have no relation, now cutting across an anticlinal, then following the strike in one direction and again in the opposite one.

How the valley was formed.—At St. Paul, on the Mississippi, and in the Minnesota above, are the banks of an ancient watercourse when at such higher level than now that the river-bed was the magnesian limestone rock, the same as that of the Mississippi, just above the Falls of St. Anthony. The existing channel of the ancient valley has probably been formed by a cataract in the great river, similar to that at St. Anthony. This view is sustained by the high islands of rock in the valley of the Minnesota, being remains of strata once continuous across it. These high islands also exist below in the Mississippi, such as Barn Bluff, at the head of Lake Pepin, and the Trempeleau hills. Some of these detached bluffs may have been formed by bends approaching each other by erosions gradually forming a neck and cutting it off. One such, nearly completed, is seen in the Dalles of the Chippewa River. The period which must have elapsed in doing this work was long, but it is probable that the volume of water, during the melting of the glaciers north of it, was greatly in excess over that of the present drainage of the Winnipeg basin. The period may have been somewhat shortened by the new water-course regaining in places some ancient one, filled only with glacial *débris*.

If we look at the valley shown on the map from Lake Traverse to Rock Island, we see that it gradually widens and contracts along its course, but, as a whole, widens as we descend. It widens where the rocks on the banks are soft, and narrows where they are harder and capable of resisting atmospheric ero-

sion, as they are near Dubuque. This is in accordance with usually received ideas, that where the stream is confined by hard banks its increased velocity, due to such contractions, may have caused the streams to abrade deeper. It is improbable that the ancient river, where it cut its way either as a cataract or in any other manner of river erosion, made the valley as wide as we now see it. It most probably underwent subsequent widening from the impinging of the currents against the foot of the high banks, thus removing the *débris* falling from the cliffs above, as well as scouring away the unbroken strata against which it washed. Even now, although the great river has disappeared, we see that the valley is still widening in some places where the river flows at the foot of the high bluffs, although, in the great majority of cases, the atmospheric erosions have covered the steep, rocky scarps with detritus, which, clothed with vegetation, preserves them from the influence of the air. Where the river now impinges against the banks composed of soft strata, we sometimes see its effect in the fresh-cut appearance of the cliff, and are led to give greater weight to similar operations in the past, when like forces were probably more intense.

I have selected one (Diagram D) such cliff in the wide part of the valley below La Crosse, which part indicates much widening since the first cutting out of the river's course. It is apparent that no stream of water could have cut down from C to AB while the opening D was available. But if we allow that cataract on the right of the diagram represents the conditions when the stream began to flow which cut the valley, then its present course is natural, the subsequent widening bringing it to the state we see on the left of the diagram.

Geologists of high character have estimated the age of the gorge at Niagara Falls on the present rates of recession, and, though the result is uncertain, it indicates the origin to be in recent geological times, although antedating the historical era. In a similar way the time required by the Mississippi to cut the gorge from Fort Snelling to the Falls of St. Anthony has been calculated by Professor N. H. Winchell,* on data that makes it vary from 6,000 to 12,000 years, by assuming that the forces in producing this result have remained uniform during this period.

That any date in geological time, capable of being expressed in definite numbers of years, can be deduced from existing observations, seems highly improbable; but whenever a condition is observed which may be referred properly to the causes now at work, whether of greater intensity or less, it is reasonable to regard the work done as of recent geological origin. We cannot neglect this uncertain method of drawing inferences, since it is the best we have, and we should endeavor, by continued inves-

* Report Geological Survey Minnesota, 1876.

tigation, to make more definite this method of finding the unknown factor, time.

Since the Falls of St. Anthony were at the junction of Minnehaha Creek, they have receded six and a quarter miles. The Minnehaha Falls, since that time, have receded three-fifths of a mile. Both streams have cut into the same formation, starting with the same height of fall. These relative rates have been as about 1 to 10. The proportion of the volumes of the two streams, judging by their present drainage areas, is about as 72 square miles is to 21,600 square miles, or about as 1 to 300. That is to say, the recession of the Minnehaha Falls has been thirty times faster than it would have been if proportioned to the volume. This may be accounted for by the greater atmospheric influence of the smaller falls, which, examination shows, keeps ahead of the effect of the water, forming a cave under the fall by the dropping down of material which the water then washes away. At the greater falls the volume of water almost constantly protects the rocks from the action of the atmosphere. Hence we must give, as said before, a very considerable influence to the operations of the atmosphere in aiding the erosions of small streams, and in demolishing cliffs where the water can remove the *débris*.

I attribute a more recent origin of the gorge of the Mississippi from Fort Snelling to the Falls of St. Anthony than to that of the Minnesota above the junction. The general map indicates that the same force which formed the valley below the junction formed that of the Minnesota above.

The hypothesis which I have heretofore advanced and endeavored to sustain, that the loss of the Winnepeg outlet along the Minnesota was due to a change of the continental slopes by a northeasterly depression, will explain this more recent origin of the St. Anthony Falls gorge. This supposed change of slope might have caused a change of outlet of the lakes about the present source of the Mississippi, so that the waters flowed out on the northeast and, falling into a depression leading southward, made this upper part of the Mississippi. When we note the great extent of the eroded valley of the Minnesota, and also the fact that all the smaller streams, like the St. Croix, Chippewa, Black and Wisconsin, have cut through the sedimentary rock down to the granitic or trap rocks, it seems improbable that the Mississippi above Fort Snelling, with its greater power, should not have accomplished as much if it had been as long at work.

Regarding the Mississippi Valley as originating as a whole by the action of a stream since the glacial ice occupied its basin, I would note that as far down as the island of Rock Island there is no decided indication of other than successive changes attending such action, and the gradual filling up of the valley

by tributary sediment after the great volume of water from the Winnipeg basin had disappeared.

Anomalies of Rock Island Rapids and Des Moines Rapids.—At Rock Island the river has left the ancient valley, which just below Rock River seems to be lost. We might have supposed that it ended here but for finding it again below Muscatine and continuous down to the Des Moines Rapids, where it is lost again. Just below, however, we find it again, and it then is continuous until it widens out into the broad expanse below the junction of the Ohio, although the river again leaves the main valley, without sufficient apparent cause, at Fountain Bluff and at the Grand Chain.

We had not time to study out where the course of the ancient valley was between Rock Island and Muscatine, but at the Des Moines Rapids we were more fortunate.

The following description of this vicinity and Diagram E will present the points that appear deserving of consideration.

The river, as it passes the town of Madison on its right bank, which is there 150 feet high, washes against a bluff composed of clay and sand arranged in a manner resembling "the ebb and flow structure." Mr. Worthen gives a good description of this formation in the Iowa Geological Report, volume i, part 1, page 187. This kind of bluff is seen only on the right bank, and extends continuously a distance of about twenty-five miles from the mouth of Skunk River down to the point D (see Diagram E), where it joins the Keokuk limestone rock just back of Montrose.

In descending the river from Madison, the river gradually recedes from this bluff, and a few miles above D the bluff is three miles from the river. A large portion of the intervening space is occupied by a sand terrace, varying from twenty to fifty feet in height above the high water; the other portion is bottom land, subject to overflow.

The river, before reaching Montrose, has a width within its banks at ordinary stages of about half a mile, and the depth of water in the pools at low stage is from fifteen to twenty feet, the bed being of sand, with no rock in place; nor is there any rock in the right-bank bluffs till just below Montrose, where it begins also in the river-bed. On the left bank or Illinois side the bluffs are of rock, the same as at the rapids, where they have been cut through by the river. This cut begins at Montrose, where the river makes a turn at a right angle to the eastward, but the depth at low water is only two to three feet, and the width at ordinary stages has widened to one mile. On both sides of the rapids the rock bluffs rise almost immediately from the water. The river on the rapids continues easterly about two miles, then turns southward and maintains this direction until all the rapids are passed and for a mile beyond; then

turns southwest until the mouth of the Des Moines River is passed, and then turns southward again.

The rock disappears in the bed on passing Keokuk; the water then deepens, flowing on a sandy bed, and resumes its width of about half a mile between its ordinary banks. On the rapids there are no considerable or permanent islands, but as you go above or below, you find them as soon as the rock-bed is left.

At Warsaw, three miles below the foot of the rapids, the Carboniferous rocks show in the bluffs, and so does the unmodified glacial drift, covered with the loess. (See Diagram F.)

The Mississippi Valley at Warsaw is about eight miles wide; part of it a sand terrace, but most of it subject to overflow.

Proceeding up the Des Moines from the mouth, we leave the limestone strata at the point H (Diagram E), and do not meet with it again, either in the river bed or bluffs, till we reach the point C, where we find it in both places, and thence all along up this valley.

In this distance between H and C the bluffs are only on the left bank or north side, and the material appears similar to that at Madison or to the loess at Warsaw, shown in Diagram F. If we examine the valley of Sugar Creek, we find the bluffs cut down as low as on the Des Moines between H and C, and all of similar material, clay and sand, but no rock in place. Nor could we find on any of the branches between ABC and DEH any rock in place or learn of any. Within these limiting lines those who have dug wells for water find it without reaching rock.

At the place marked K on the sand terrace a well fifty feet deep encountered no rock, although this was as far down as the level of low water in the river.

The width of the main valley above Fort Madison is nearly the same as below Keokuk, and if we prolong the line of bluff between these two places, it will include a space between them where there is no known rock *in situ*, and which it appears reasonable represents the ancient channel, since filled up.

The loess formation.—This name has been given in this country to a fine material deposited over all the other formations, including the glacial deposits near the river, but not upon the river sand-and-gravel terraces, which are therefore the more recent. It has a thickness of many feet in places. It is generally regarded as having been deposited in quiet water. In many places it is nearly uniform in thickness, conforming with the previous irregularities of the surface, as snow lies where it has not drifted. This would be brought about by a silt laden fresh-water current spreading out over one more dense and quiet, through which the fine silt dropped. Such conditions would exist in salt water, and the silt would prevent the exist-

ence of many kinds of marine life, and would contain the animal remains brought from the fresh-water streams.

The margins of the loess deposits are not well defined, and do not appear to have been investigated as they should be. The deposit is well shown near Rock Island, but does not appear as high up as Dubuque (so far as I know). It extends up the Missouri as far as Sioux City, and the Missouri River made immense deposits into the body of water in which the loess was laid down. From the absence of marine fossils, this body of water has been regarded as fresh and without connection with the Gulf of Mexico except through an outlet. Judging by what I know of the deposits, I should think it did not connect with our present Great Lakes, and that a tongue of land or promontory separated the arms extending up the Mississippi and Missouri Rivers.

The streams which brought this fine loess material which has been so spread out must have brought down heavier material along the bottom that fell as soon as it reached the enlarged section, just as rivers make their deposits of heavy material now on reaching their natural receptacles. A most interesting case in point is in the deposits made in the Great Salt Lake in quaternary times, where its terraces show a level nearly a thousand feet above its present surface. The streams, like the Weber, built out the terrace at their point of discharge in the fan shape of a river-bar up to this terrace level near the ancient shore, and extending back in the river valley, which must then have appeared as a fiord. Although the ancient Weber River deposit diminished in amount as it extended into the ancient lake, yet it terminated quite abruptly. I think, then, there is good reason to regard the bluff-deposits at Fort Madison and vicinity, on the west side of the valley, as belonging to the loess period, and not to glacial times. These deposits are where streams would bring them from the northwest, while the glacial deposits seem to have come from the northeast. This filling up of the ancient valley of Keokuk and Madison, and also in the neighborhood of Rock Island, is where the mouths of considerable rivers probably were during the existence of the large body of water in which the deposition of the loess was made.

Formation of rapids since the loess.—When the body of water of the loess period disappeared and the emergence of the land again took place, the Mississippi did not regain its ancient channel, but cut the new one now occupied. These rapids cannot be accounted for by any special hardness of the rocks, but their resistance is increased because of the dip of the strata being nearly that of the river-slope. When the river was at a higher level and made the sweeping bend above Montrose so as to wash the loess bluffs, but little more erosion would have

been required there to have carried the river back again to its ancient channel during some extraordinary flood, and yet it might have been that the new channel would even after this remain the permanent one for ordinary stages.

Such an explanation as this may be applicable to the cases at Fountain Bluff and at the Grand Chain on the Mississippi just above the mouth of the Ohio, and to the almost incomprehensible changes of course in the Lower Ohio itself, shown on the general map.

Another interesting supposition may be made that the Mississippi in the last terrace period might have succeeded in washing down the bluffs, separating it near Burlington from the Crooked Creek flowing into the Illinois. (See Diagram 1, sheet 4.) The new channel would have double the descent to the mouth of the Illinois of the existing one, and we might have gained a new course for the river, leaving a larger ancient channel occupied by a smaller stream, and there would have been set at work a new cause to modify all the valley of the Illinois River and all the Mississippi above.

Summary of principal points presented.—I will summarize the principal facts that seem to be made out along the course of the Minnesota and Mississippi:

1. That the Minnesota Valley and the Mississippi Valley above the Ohio have been, as a rule, formed since the deposition of the glacial drift, for this exists in unmodified and modified forms in the banks of the river; and that the Winnipeg basin drained out southward along it.

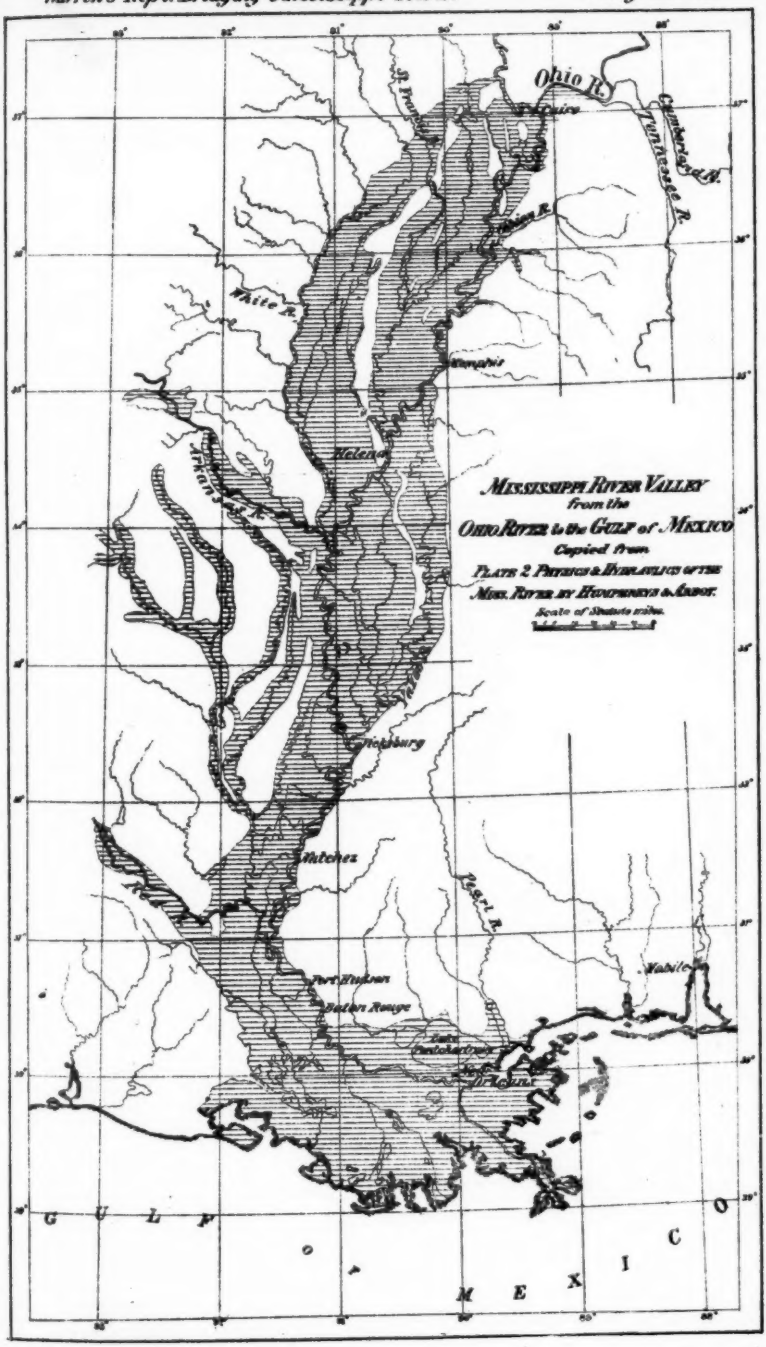
2. That the loess deposits, extending up to the neighborhood of Savannah, are later than the last glacial drift.

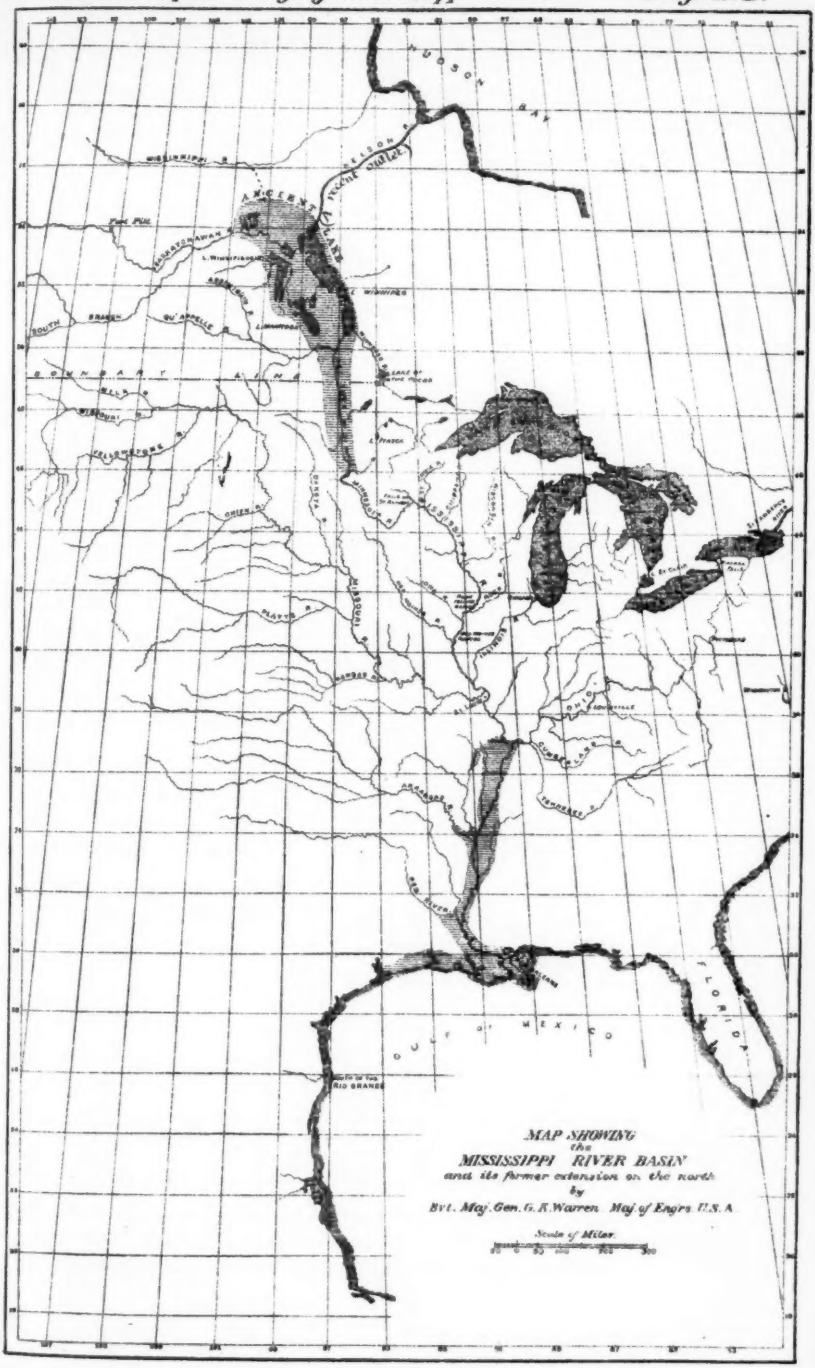
3. That channels like those at the Des Moines Rapids and river terraces in that vicinity are more recent than the loess.

Explanatory hypotheses.—I have advanced this hypothesis of southern elevation and northern depression several times before and illustrated its effect on the Minnesota and on the Wisconsin Rivers, and in the first instance considered what the results would be in contiguous regions, and how far facts seemed to correspond, and it is unnecessary to repeat them here.

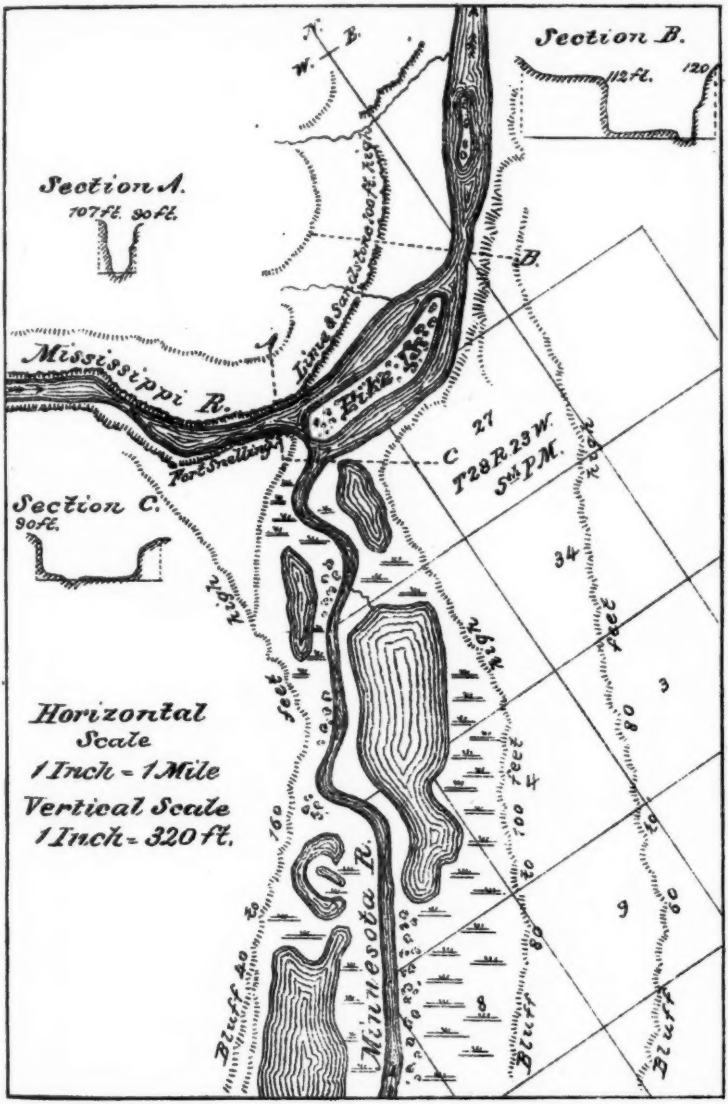
The hypothesis appears to be in accordance with a number of very important facts, and is consistent with observations as to southern elevation and northern depression now going on. It explains, by one widely exerted influence, many effects which, on the grounds of glacial action alone, requires many special glaciers, and it will answer as an explanation of the coming on and disappearance of the loess body of water, and for the change in the drainage of Lake Winnipeg.

I think this change of relative elevation south and depression north has been probably reversed at some periods, and repeated. This is important, for, if we can show that any movement of


Ohio R.
Cumberland R.
Tennessee R.
White R.
Memphis
Helena
Vicksburg
Natchez
Red R.
Yazoo R.
Port Hudson
Baton Rouge
Mobile
MISSISSIPPI RIVER VALLEY
from the
OHIO RIVER to the GULF of MEXICO
Copied from
PLATE 2 PHYSICS & HYDRAULICS OF THE
MISS. RIVER BY HUMPHREYS & ABBOT.
Scale of Statute miles.
G U L F O F M E X I C O

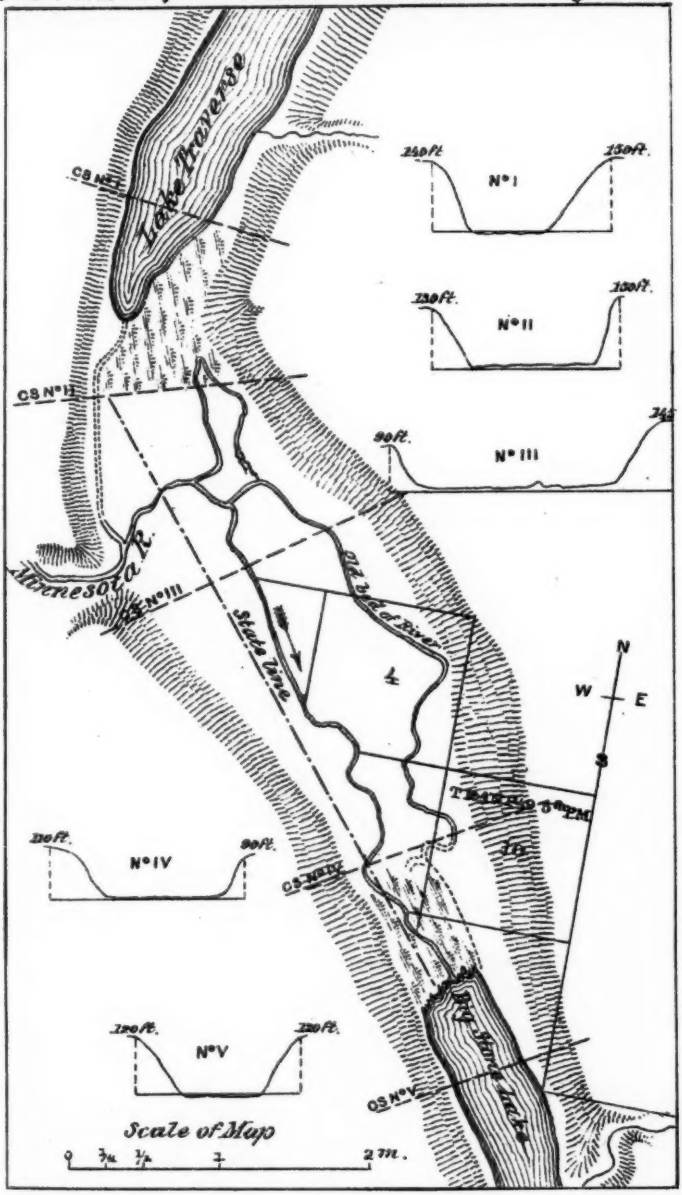

HUDSON BAY
ANCIENT LAKE AGASSIZ
RED RIVER
MISSOURI R.
MISSISSIPPI R.
OHIO R.
ARKANSAS R.
GULF OF MEXICO
FLORIDA
MAP SHOWING
the
MISSISSIPPI RIVER BASIN
and its former extension on the north
by
Bvt. Maj. Gen. G. K. Warren. Maj of Engrs U.S.A.
Scale of Miles.

Warren's Rept. Bridging Miss. R. *Diagram C.*

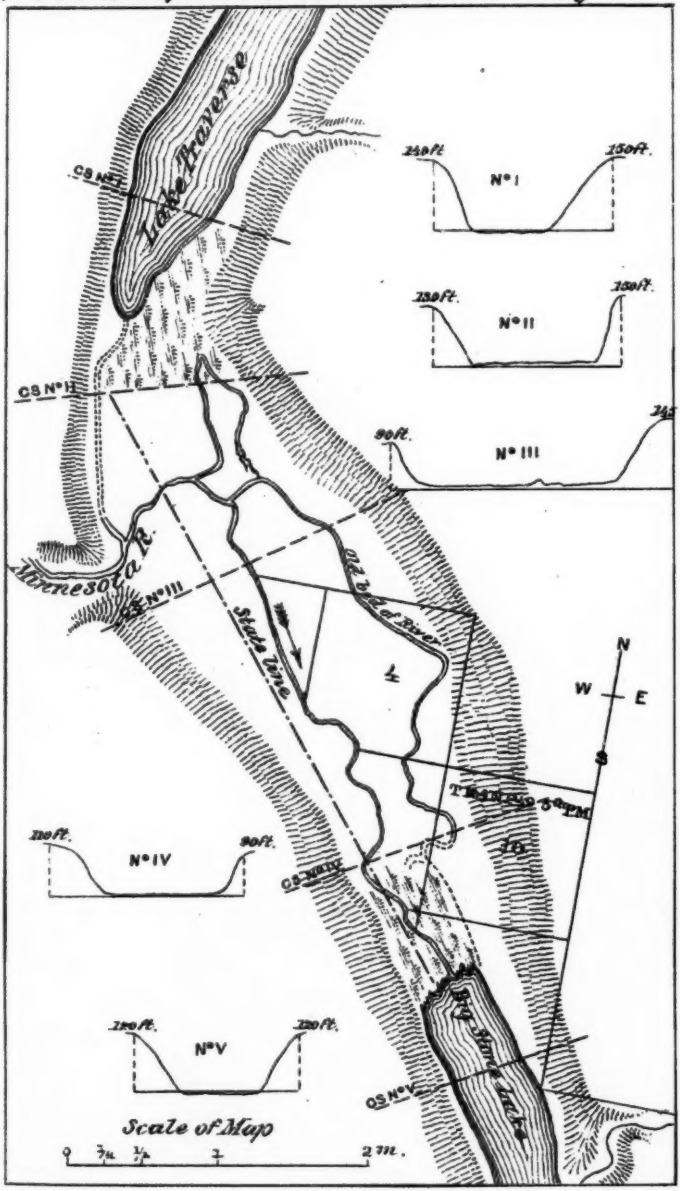


Map showing the river valley where the Minnesota and Mississippi Rivers join, with sections of the valley below the junction, and on each above the junction.

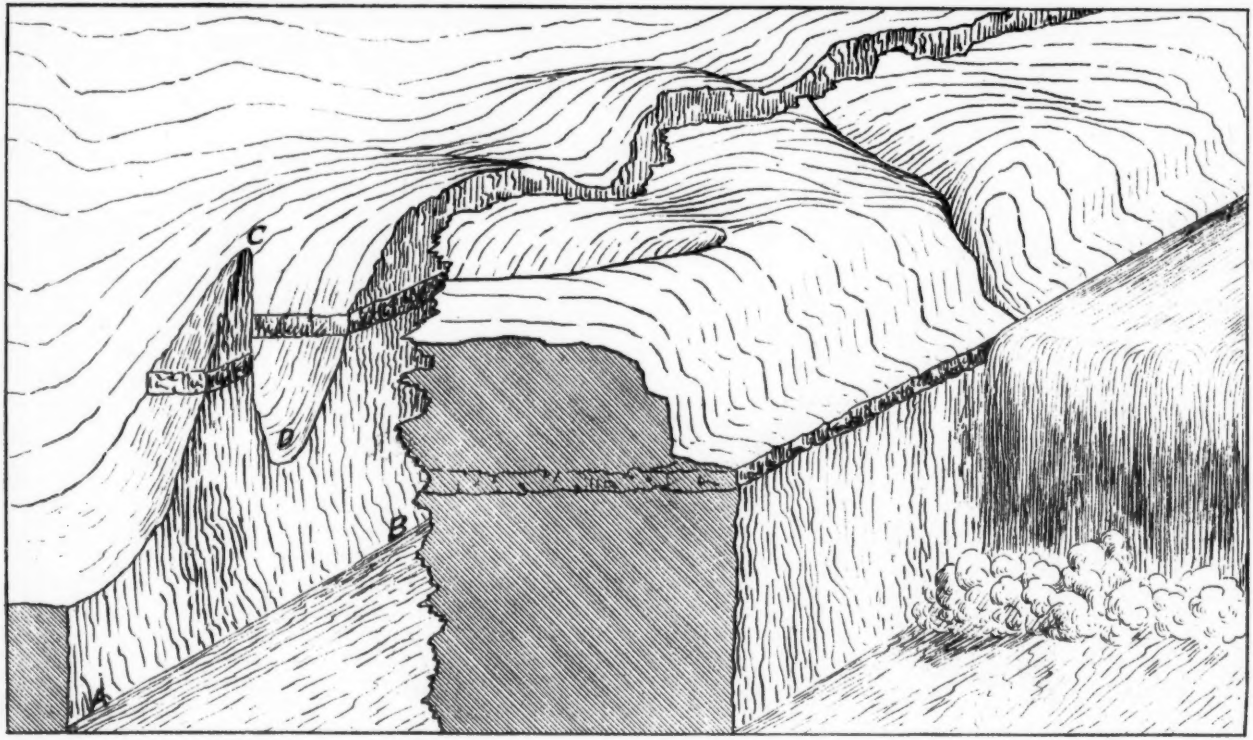
Warren's Report on Minnesota River. Diagram C.



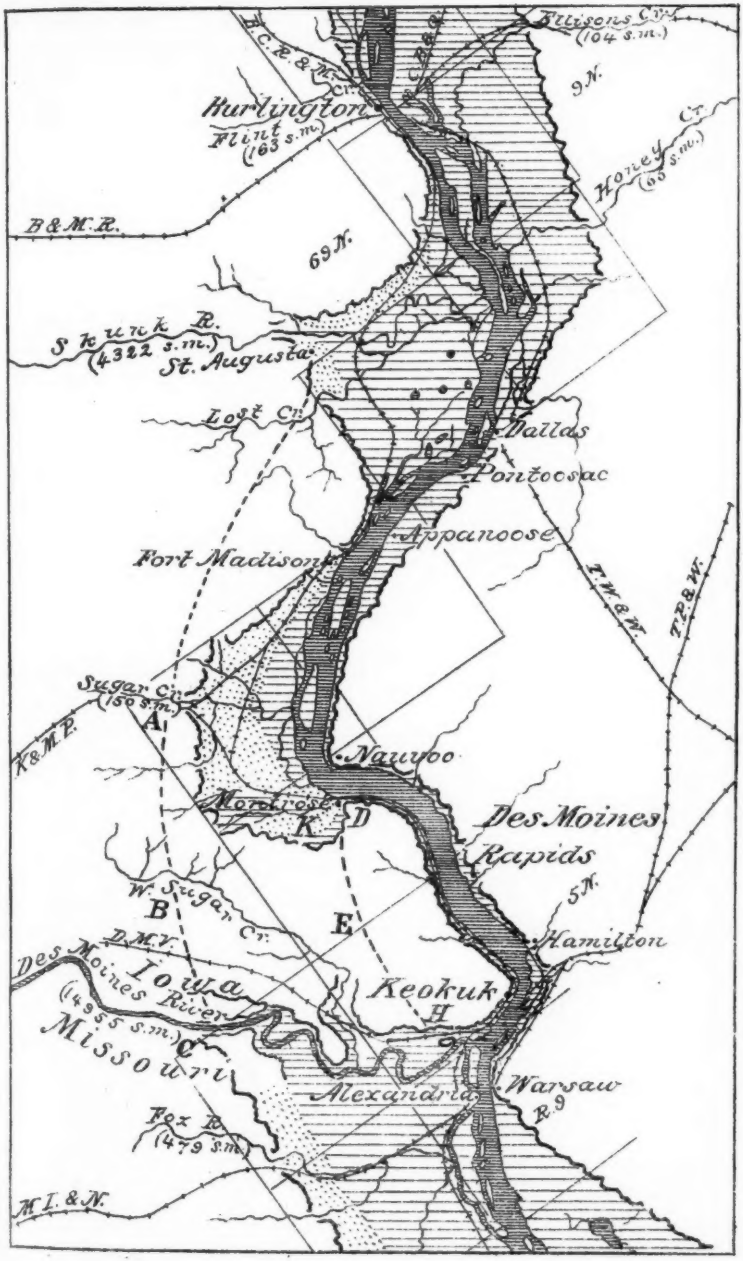
Warren's Report on Minnesota River. Diagram C.



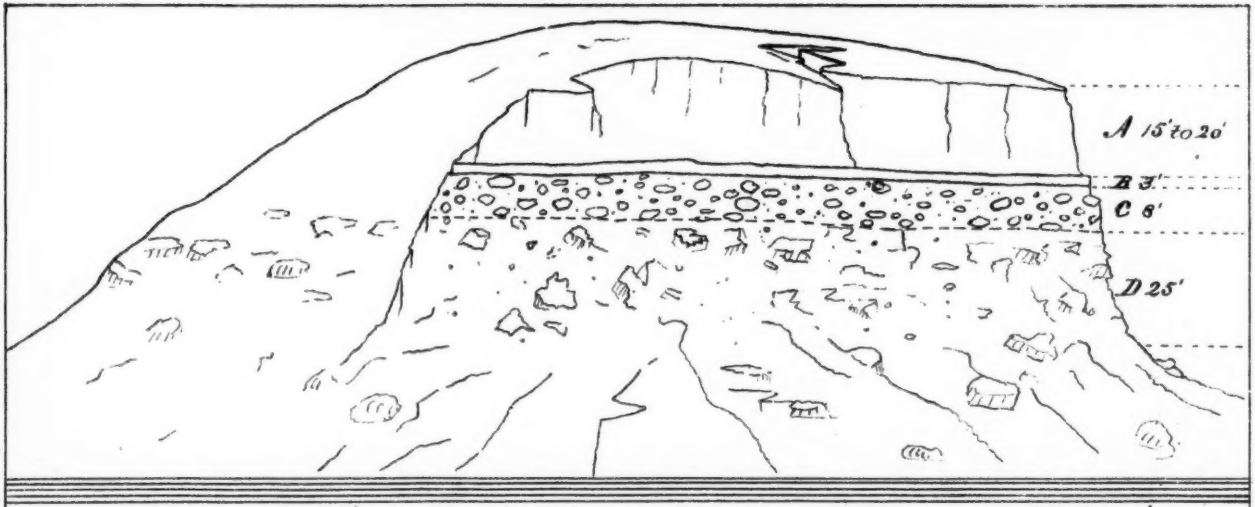
Warren's Rep't. Bridging Miss. R. *Diagram D.*



Warren's Rep't. Bridging Miss. R. *Diagram E.*



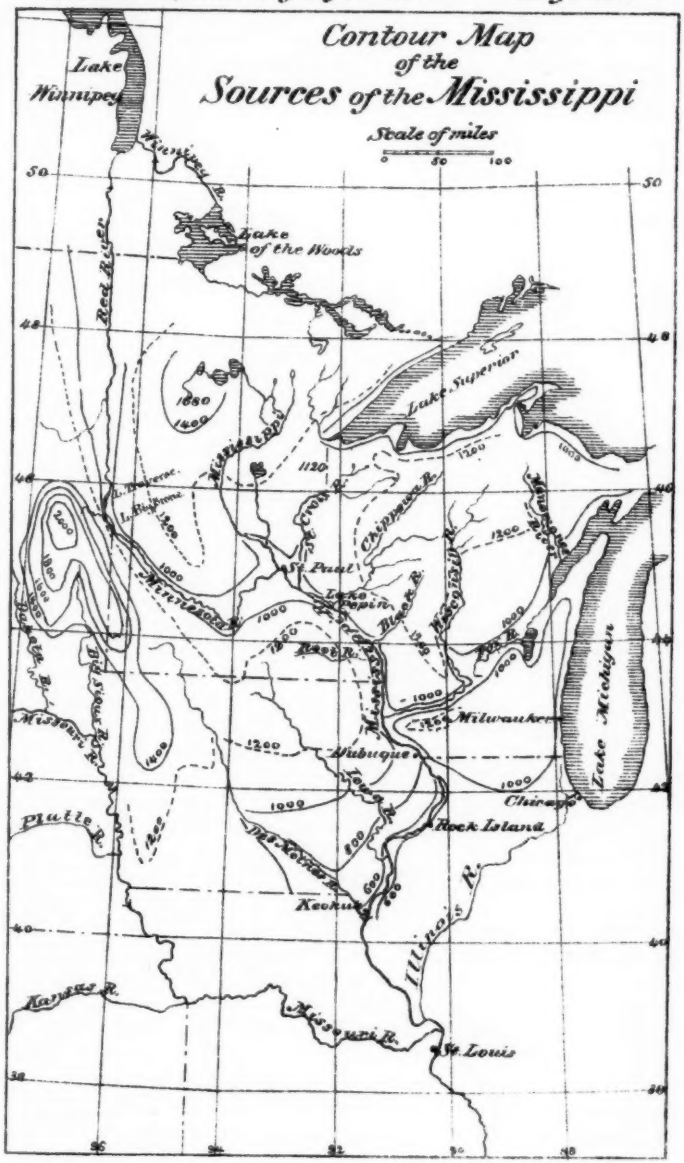
Warren's Rep't. Bridging Miss. R. *Diagram F.*



Section of Mississippi River Bluffs at Warsaw Illinois

A is a very fine yellow sand and clay widely developed. B is a bluish clay and fine sand C is rounded hard bowlders from small gravel up to 400 lbs., mixed with sand. D is composed of angular blocks from over a ton weight down to small stones, mingled without order; with coarse and fine sand and clay, showing no selection or sorting. The rocks are trap, porphyry, granite gneiss or syenite, hard brecciated limestone &c. The upper carboniferous shales in vicinity exhibit local displacements

Warren's Rep't Bridging Miss. R. *Diagram G*



the earth's crust is a recurrent phenomenon, it may help us to trace out its cause.

Approximate practical conclusions.—The only practical conclusion which can be drawn from the preceding discussion seems to be that the origin of the excavation of the valley is comparatively modern, and that it was from the operation of forces producing probably uniform results, and in a way that we have some approximate comprehension of it in general, from our knowledge of special localities.

Note.—Descriptions of the best known sections of the valley follow in the report.

ART. LI.—*On some points in Lithology;* by JAMES D. DANA.

[Continued from page 343.]

4. *Containing Quartz or not.*—Since quartz is the most universal of the materials of rocks, its presence is least entitled to be made a basis for distinctions among them. In sedimentary deposits, the original of many of the crystalline kinds, it is a very common ingredient owing to their mode of origin, and its more or less abundance is a matter of no great geological importance. Sufficient reasons exist, therefore, for the course pursued by recent writers on lithology in making the presence or not of quartz even in crystalline rocks a basis only for a subdivision under a *kind* of rock. Thus there is under dioryte, *quartz-dioryte;* under trachyte, *quartz-trachyte;* under felsyte, *quartz-felsyte;* and so in other cases.

Syenyte is defined by such authors as consisting chiefly of orthoclase and hornblende. Now a rock made prominently of these minerals often contains also quartz; and the name for the quartz-bearing kind, which a system of lithology using the above-cited terms would seem to require, would be *quartz-syenyte.* To call it "hornblende-granite," as is often done, is at variance with the system which uses the word *quartz* as an affix in other cases.

This term "hornblende-granite" is at variance also with the fundamental idea and nature of granite. Granite is eminently a potash-bearing rock. The feldspar is a potash-bearing species; and the mica, whether muscovite or biotite, yields on analysis little less potash than the feldspar, the amount being eight to twelve per cent. These two micas are both present in most granite, gneiss and mica schist: and they are so near akin that they sometimes occur combined in a single crystal—the presence of a little iron in the original material having apparently determined the formation of the latter where it occurs. On the contrary the hornblende of such rocks contains usually

less than one per cent of alkalies, and rarely in any kinds over five per cent. Looking to chemical and mineralogical constitution—the true criterion as to identity among rocks—the strongly drawn line is between the mica-bearing series and the hornblende-bearing series. Granite belongs to a *mica* and *potash-feldspar series;* and syenyte, whether quartzless or quartz-bearing, to a *hornblende* and *potash-feldspar series.*

Moreover, the original syenyte, from Syene, Egypt (to which the name "syenites" was applied by Pliny and other ancient writers) is a quartz-bearing "syenites." The larger part of the syenyte of all Archæan regions is quartz-bearing. The quartzless kind is seldom met with in Eastern North America, or, as far as explored, in the Rocky Mountain region. There are hornblende granites; but these are granites which contain hornblenbe *in addition to* the mica and other ingredients.

Transitions are common between granite, hornblende-granite and quartz-bearing syenyte; but they are so also between these and quartzless syenyte, between syenyte-gneiss and ordinary gneiss, between hornblende schist and mica schist, and between these and other rocks. They are throughout lithology a source of difficulty in characterizing kinds of rocks, as already stated. But they do not set aside the fact that the division between the mica and potash-feldspar series and the hornblende and potash-feldspar series is the most reasonable on mineralogical and chemical grounds.

5. *Containing "Plagioclase."*—The fact that the composition of the triclinic feldspars between the extreme species albite, a sodium-aluminum tersilicate, and anorthite, a calcium-aluminum bisilicate, may be explained by supposing them combinations of these species through isomorphous substitutions of the tersilicate and bisilicate (the amount of sodium present determining the amount of tersilicate in the combination, and the amount of calcium that of bisilicate) was immediately followed by the assumption that these two silicates combined *indefinitely*, and, therefore, that all the triclinic feldspars were essentially one species, and for this reputed species the name *plagioclase* has been used. Some ground for the assumption was found in the analyses of the feldspars; but how much was uncertain, because, in several cases, *mechanical* mixtures of one species with another had been ascertained to exist in crystals. Now that Des Cloizeaux has proved, by optical investigations, that several of the species of triclinic feldspars are really species, that is, that the combinations of the two silicates, the tersilicate and bisilicate, are based on *definite* ratios, as in combinations in other departments of chemistry, and that there are not indefinite blendings, the term "plagioclase" has become merely a synonym for "triclinic feldspar."

The consequences to lithology of this introduction of the term "plagioclase" were unfortunately great. It was made a sufficient definition of a rock to say that it consisted of "*plagioclase* and hornblende," "*plagioclase* and augite," and so on; and this is now common in recent memoirs on rocks. It was a convenient idea; for an examination with the microscope is made in a hundreth part of the time required for a chemical analysis.

Now this word "plagioclase" covers compounds varying in the silica afforded by analyses from 43 to 69 per cent; and in the alkali from all lime (20 per cent) to all soda (12 per cent.) Anorthite, the lime feldspar, is not oligoclase, even if to the two a common name be applied; they still differ 20 per cent in silica (which is one-fifth the mass), and also in the alkali present. Expressions like "consisting of plagioclase and hornblende," as in the definition of dioryte, have consequently an immensely wide signification; for the word dioryte is made to cover oligioclase-dioryte, labradorite-dioryte, and anorthite-dioryte.

This confounding of things thus unlike may be called simplifying the science of lithology; but it is a confounding of important distinctions in the view of those who are interested in a definite knowledge of rocks, and in the important geological questions connected with their constitution. Some lithologists recognize the bearings of such questions, and use the qualified terms for the kinds of dioryte above cited. But the most recent turn is in the other direction. Rosenbusch's learned work, the latest, says that the rocks of the "family" of diabase consist of "plagioclase and augite," and that the feldspars, oligoclase, labradorite and anorthite have been observed in them. Dioryte is defined as a "family" of older rocks consisting essentially of "plagioclase and hornblende." Had the different *kinds* of rocks embraced in these families been separately stated and described, the account might have been satisfactory. But, under both diabase and dioryte, the term "plagioclase" is used as if sufficiently defined in itself, and under dioryte it is given with its aggregate signification alone, no mention being made of the particular feldspar the dioryte of different localities contains.*

If a dioryte happens to be porphyritic, it is at once put into the grand division of dioryte-porphyry, when the only distinction may be that the feldspar is in defined crystals, the chemical and mineralogical constitution being identical. But if the feldspar of one dioryte contains twenty per cent of silica more than another and no soda at all, it is still all dioryte.

*It should be here acknowledged that Rosenbusch's very valuable work bears the title "Mikroskopische Physiographie der massigen Gesteine" so that it does not claim to cover the subject of the chemical or mineralogical constitution of rocks.

In geology, it is essential to a thorough study of the questions it has before it that the kinds of feldspars should not be massed under a common name; and that in every case the investigation should be considered unfinished until not merely the amount of silica in the rock is accurately ascertained, but also the particular species of feldspar is correctly and fully determined, however great the labor required to reach a conclusion. The use of the term *plagioclase* in such a case is an acknowledgment of incomplete work, and should be so treated.

But the objection to the use of the term "plagioclase" is still stronger than has been stated. It now includes not only the soda-lime feldspars from anorthite to albite inclusive, but also part of *potash*-feldspar. The establishment, on an unquestionable basis, of Breithaupt's *microcline* by Des Cloizeaux, and his further observations that this triclinic potash-feldspar is a very common mineral, much of what was supposed to be orthoclase belonging to it, has extended the range of "plagioclase," until it is now almost an equivalent of the general term feldspar, so that "*plagioclase* and hornblende" has, as to chemical constitution, the same signification now with *feldspar* and hornblende.

6. *Rocks consisting of a triclinic feldspar and mica.*—The term dioryte, formerly defined as a rock consisting of oligoclase or albite and hornblende, has been introduced into the name of a series of rocks containing no hornblende, but mica instead. Thus: "*mica-dioryte*" is defined as a "plagioclase-mica rock" in which mica is substituted partly or wholly for hornblende, and it is called mica-dioryte whichever of the triclinic feldspars be present, even if anorthite. This change in the use of the name dioryte so as to include a rock containing no hornblende, makes "plagioclase" the essential constituent, and places mica and hornblende in a subordinate position, as the heads only of subdivisions.

The remarks made respecting syenyte apply equally here; and also those respecting "plagioclase." A mica-dioryte is, like granite, eminently an alkali-yielding rock, the mica (biotite) affording usually ten per cent of potash; and as granites often contain oligoclase as well as orthoclase, the amount of potash and soda in a "mica-dioryte" and a granite may not be very widely different. Dioryte, on the contrary, is prominently a hornblende rock.

Looking to the mineralogical and chemical constitution of the rocks, we are naturally led to recognize along side of a mica and *potash-feldspar* series, which is headed by granite, also a mica and *soda-lime feldspar* series, and to include in the latter the so-called mica-diorytes.

7. *Hornblendic or Augitic.*—Hornblendic and augitic rocks stand apart as a general thing in all systems of lithology. Yet

the minerals are essentially identical in chemical composition, and related in crystallization, though different in their occurring crystalline forms and in the angle of the cleavage prism. The identity in composition is so close that chemical analysis is not able to distinguish them. Hence the related eruptive rocks of the hornblendic and augitic series (or those containing the same species of feldspar in like proportions) must have originated in material of essentially the same chemical composition. The relation between the two minerals is thus far closer than between the triclinic species of feldspars.

Nevertheless, too much importance is not given them when each is made distinctive of an independent series of rocks; for the very wide extent to which augitic rocks retain unvaryingly their augitic characters—such rocks constituting full two-thirds of the earth's eruptive masses—shows that the special conditions producing augite, instead of hornblende, whatever they are, have often acted on a vast scale in the earth's history. And so, also, the very wide distribution of hornblendic rocks, especially among the metamorphic kinds, is evidence of a like comprehensive influence of the conditions needed to make hornblende in place of augite. The geological importance of the distinction is reason enough for recognizing it in lithological systems.

8. *Massive or Schistose.*—Massive structure is often made *prima facie* evidence of igneous origin. Granite, with hardly a questioning thought, has usually been placed solely among eruptive rocks. The igneous origin of dioryte even now is hardly left open to investigation by some lithologists. Serpentine has been in the same category, though at present there are advocates of its metamorphic origin. And so other massive rocks are too likely to be set down as eruptive without a fair investigation. No two rocks are put farther apart in some lithological systems than granite and gneiss; and yet, none are more closely related in constitution and all essential characteristics.

The following are reasons for disregarding this distinction of massive or schistose in classifying rocks, and for allowing a massive structure little weight in deciding the question as to eruptive or metamorphic origin.

(1.) *Massive rocks may be both metamorphic and eruptive.* Granite, syenyte, with dioryte and other hornblendic rocks, are examples of massive rocks that are of both modes of origin. Many localities where kinds of these rocks occur metamorphic have been described. I will mention two or three from the many I have observed in New England. (*a*) Ten miles east of New Haven, Connecticut, in a railroad cut at Stoney Creek, a bed of granite, having a small northward dip, changes gradually to gneiss, and then to gneiss with some very micaceous mica

schist, so that within thirty yards from east to west these three rocks are found constituting the same bed; and the granite is a part of the general gneissic formation of the region. (*b*) The labradorite-dioryte two miles west of New Haven graduates rather abruptly above and below, and also laterally, from a massive rock into a slaty chloritic mica schist, and does this so often and variously, that there is no reason for questioning its metamorphic origin. (*c*) A hornblende (or actinolite) rock, just northeast of Bernardston, of a massive kind, occurs among thin schistose beds of mica schist and hornblendic schist and is part of a series of metamorphic strata. From a hand specimen either of these rocks would be pronounced eruptive; but observation in the field proves that they are not so.

(2.) *Certain kinds of mineral constituents are almost sure to make a massive metamorphic rock when the process of metamorphism is one attended with much heat.* Hornblende and augite are minerals of this kind. Both are rather fusible, and crystallize readily, so that heat easily obliterates all traces of bedding. This principle alone will account for the fact that the rocks northeast of Bernardston, alluded to above, are massive wherever hornblende is the chief ingredient. It explains also the existence of the massive labradorite-dioryte among the schists west of New Haven. Feldspar also, when alone, or accompanied by quartz without any associated mica (as in felsyte, quartz-felsyte, granulyte), is almost sure, under the circumstances mentioned, to make a rock, with the bedding obliterated, in other words, a massive rock; and only with a low degree of heat in the metamorphism, would any original bedding be retained. And even if hornblende is present, there is the same tendency to massive forms. Serpentine is another species that makes almost necessarily a massive rock, whatever the method of origin, because the mineral has nothing in its structure that favors any other condition.

(3.) *Pressure may be a source of schistosity or foliation, and it may also obliterate bedding.* On the first of these points illustration is not necessary. As to the second, there are many examples in the crystalline limestone region of Western New England, both in Vermont, Massachusetts and Connecticut. At West Rutland, Vermont, as first observed by Prof. Edward Hitchcock, many limestone beds have been cemented by the pressure which gave them their high dip into a bed of great thickness, so that masses as large as a moderate-sized house could be cut out if needed. The component beds are easily distinguished in the southernmost of the three quarries. Moreover, in the middle of the same valley the metamorphism of the limestone stratum was not complete enough to obliterate the fossils—shells, corals and crinoids being distinguishable; so that there could have been

no fusion to produce the coalescence. As this welding of beds is so perfect in the limestone, it is reasonable to believe that a similar cause may have acted in the case of feldspathic, hornblendic and augitic rocks, without even the aid of incipient fusion.

(4.) *The sedimentary beds which have been converted into crystalline rocks were often originally massive.*—This is the condition of most conglomerates, and often of coarse sandstones. In such cases there would be no bedding to obliterate; and the production of a massive rock would be a natural result of the metamorphism, whether the heat attending it were great or small. Part of the metamorphic granite of the world may therefore never have been in a pasty state; and so also part of the metamorphic hornblende rocks; some metamorphic felsyte beds, certainly those that are of conglomerate origin, were originally massive.

There is hence reason enough for neglecting the distinction of massive and schistose in drawing out a system or classification of rocks, and for making the question of origin in the case of either kind, the massive no less than the schistose, a subject for careful investigation.

9. *Metamorphic or Eruptive.*—The question whether a crystalline rock is metamorphic and *in place*, or eruptive, is of the highest geological interest; for it is a question as to origin. At the same time, no subject, if we exclude the part of metamorphism relating to the obviously schistose rocks, is in so unsatisfactory a state. With some authors, as above intimated, the question so far as it relates to *massive* crystalline rock is not an open one. On the other hand, when investigation has taken place, opposite opinions have generally been reached. The remedy of this is to be found in more thorough study from a wider basis of facts.

Were the question in all cases rightly decided, lithology would be able to study and compare the two series, and give greater completeness and higher geological value to the descriptions of rocks. Applying different names to the like rocks in the two series is not necessary, unless there is some strong geological reason in favor of it; for when a rock occurs both metamorphic and eruptive the fact is best exhibited if that rock has but one name. The writer has proposed to distinguish the metamorphic under any *kind* of rock by adding to the name the prefix *meta;* for example, *dioryte* for the eruptive and *metadioryte* for the metamorphic part. But *meta* is here used simply as an abbreviation of the word *metamorphic*, not to indicate a difference of *kind* in the rock.

Conclusions.

The principal points with regard to rocks which have been brought out in this paper, are the following.

1. The necessities of the science of Geology constitute the most prominent motive for distinguishing *kinds* of rocks; and they should determine to a large extent upon what characters distinctions should be based.

2. In determining the rocks to be grouped as one in *kind* under a common name, near identity in the chemical and mineral composition of the chief constituents is the main point to be considered; not near identity in their crystalline forms, for isomorphism presupposes diversity of composition.

3. Distinction of *kind* should be based on difference in chemical and mineral constitution as regards the chief constituents. When such difference exists, rocks are different in *kind*, and need, for the purposes of geology, distinct names. If it does not exist, the distinction is only that of *variety*; unless (as in the case of trachyte and felsyte), the very wide extension of the rock under persistent characters makes a distinction of name important to geology.

4. It follows from the preceding, that differences in texture: as coarse, or fine, or aphanitic; porphyritic, or non-porphyritic; stoney throughout, or having unindividualized portions among the stoney grains; and differences in microscopic inclusions; are no basis for a distinction of *kind* among rocks, but only of *variety*; and that *porphyritic structure* is of hardly more consequence than coarse or fine granular.

5. No marked change in the constituents of the earth's erupted material occurred after the close of the Cretaceous period, or just before the commencement of the Tertiary era; and, hence, no ground exists for the distinction of "older" and "younger" among eruptive rocks. The "younger" eruptive rocks are essentially like the "older" in chemical composition and their chief mineral constituents; and they differ when at all only in texture and some other points of as little importance —qualities that distinguish merely varieties, and which have proceeded from greater prevalence in these later times of subaerial eruptions.

6. Since "plagioclase" is not the name of a mineral species, —several minerals, of widely different compositions being embraced under it—it is a confounding of differences and resemblances to speak of it as a constituent of a rock. And since it now includes, through the defining of the feldspar microcline, a large part of potash feldspar, which had been supposed to be orthoclase, it has become almost synonymous with the term feldspar. The "simplicity" its adoption has been

supposed to give to lithological system would be greater if "feldspar" were substituted, and with its present range of constitution, the evil would be hardly less.

7. Rocks differing mineralogically, and not chemically, like related hornblendic and augitic rocks (the minerals hornblende and augite being dimorphous), are rightly made distinct rocks, since the difference has depended, to a large extent, on wide-reaching geological operations or conditions, and is, therefore, of great geological signficance.

8. Since quartz is the most widely distributed and therefore the least distinctive of the minerals of rocks, it may rightly be regarded as of subordinate importance in the distinguishing of rocks, and hence not only such names as *dioryte* and *quartz-dioryte*, *trachyte* and *quartz-trachyte*, etc., are acceptable, but also *syenyte* and *quartz-syenyte*.

9. Biotite being closely like muscovite in composition, and not less common than it in granites, gneisses and mica schists, and being, moreover, unlike the mineral hornblende in chemical constitution and formula, the rocks in which biotite is a chief constituent cannot rightly be put in the same group with hornblende rocks; or those in which hornblende is a chief constituent in a group of mica-bearing rocks. Consequently the name "mica-dioryte," for a rock containing no hornblende, and the name "hornblende-granite" for a rock containing no mica but hornblende instead, imply alike false relations.

The discussion suggests the following additional remark:

The incapabilities of the microscope and polariscope have favored the use of the term "plagioclase," and have led some investigators to overlook or slight distinctions in chemical constitution. Lithology is to receive hereafter its greatest advances through chemical analyses; for chemistry alone can clear away the doubts the microscope leaves, and so give that completeness to the Science of Rocks which geology requires for right and comprehensive conclusions.

Moreover the researches made in the laboratory to be of real geological value should be, if possible, supplemented by investigations in the field as to transitions among the rocks, and as to other kinds of relations. This field work has often been well done, but not so by all lithological investigators.

The principles presented lead to the following subdivisions in an arrangement of crystalline rocks, exclusive of the Calcareous and Quartzose kinds. Since leucite is a potash-alumina silicate, like orthoclase and microcline (it affording twenty per cent or more of potash), it is here referred to the same group with the potash feldspars; and nephelite, sodalite and the saussurites being eminently soda-bearing species, they are

included with the soda-lime feldspars (anorthite to albite). This reference for lithological purposes of these minerals is sustained by their resemblance to the feldspars in constituents, and also in the quantivalent ratios between the alkalies, alumina and silica, this ratio being in leucite 1 : 3 : 8, as in andesite, and in sodalite and nephelite 1 : 3 : 4, as in anorthite. The term *potash feldspar*, as used in the headings below, is hence to be understood as covering orthoclase, microcline and leucite; and *soda-lime feldspar*, as including the triclinic feldspars from anorthite to albite, and also nephelite, sodalite and the saussurites.

The arrangement is as follows. In the first series, the rocks graduate into kinds which are all feldspar, and into others that are all mica; and yet the amount of potash present is approximately the same.

I. The Mica and Potash Feldspar Series: including Granite, Granulyte, Gneiss, Protogine, Mica schist, etc., Felsyte, Trachyte, etc., and the Leucite rock of Wyoming.

II. The Mica and Soda-Lime Feldspar Series: including Kersantite, Kinzigite; and the nephelitic kinds Miascyte, Ditroyte, Phonolyte, etc. (These nephelitic kinds belong almost as well in the preceding series).

III. The Hornblende and Potash Feldspar Series: including Syenyte (with Quartz-syenyte), Syenyte-gneiss, Hornblende schist, Amphibolyte, Unakyte (this last containing epidote in place of hornblende); and the nephelitic species Zircon-Syenyte, Foyayte.

IV. The Hornblende and Soda-Lime Feldspar Series: including Dioryte (with Propylyte), Andesyte, Labradioryte (or Labrador-dioryte), etc., and the saussurite rock, Euphotide.

V. The Pyroxene and Potash Feldspar Series: including Amphigenyte.

VI. The Pyroxene and Soda-Lime Feldspar Series: including Augite-Andesyte, Noryte (Hypersthenyte and Gabbro in part), Hypersthenyte (containing true hypersthene), Doleryte (comprising Basalt and Diabase), Nephelinyte, etc.

VII. Pyroxene, Garnet, Epidote and Chrysolite Rocks, containing little or no Feldspar: including Pyroxenyte, Lherzolyte, Garnetyte (Garnet rock), Eclogyte, Epidosyte, Chrysolyte or Dunyte (Chrysolite rock), etc.

VIII. Hydrous Magnesian and Aluminous Rocks, containing little or no Feldspar: including Chlorite schist, Talcose schist, Serpentine, Ophiolyte, Pyrophyllite schist, etc.

ART. LII.—*On the Equilibrium of Heterogeneous Substances;* by J. WILLARD GIBBS.* Abstract by the author.

IT is an inference naturally suggested by the general increase of entropy which accompanies the changes occurring in any isolated material system that when the entropy of the system has reached a maximum, the system will be in a state of equilibrium. Although this principle has by no means escaped the attention of physicists, its importance does not appear to have been duly appreciated. Little has been done to develop the principle as a foundation for the general theory of thermodynamic equilibrium.

The principle may be formulated as follows, constituting a criterion of equilibrium:

I. *For the equilibrium of any isolated system it is necessary and sufficient that in all possible variations of the state of the system which do not alter its energy, the variation of its entropy shall either vanish or be negative.*

The following form, which is easily shown to be equivalent to the preceding, is often more convenient in application:

II. *For the equilibrium of any isolated system it is necessary and sufficient that in all possible variations of the state of the system which do not alter its entropy, the variation of its energy shall either vanish or be positive.*

If we denote the energy and entropy of the system by ε and η respectively, the criterion of equilibrium may be expressed by either of the formulæ

$$(\delta\eta)_\varepsilon \leqq 0, \tag{1}$$

$$(\delta\varepsilon)_\eta \geqq 0. \tag{2}$$

Again, if we assume that the temperature of the system is uniform, and denote its absolute temperature by t, and set

$$\psi = \varepsilon - t\,\eta, \tag{3}$$

the remaining conditions of equilibrium may be expressed by the formula

$$(\delta\psi)_t \geqq 0, \tag{4}$$

the suffixed letter, as in the preceding cases, indicating that the quantity which it represents is constant. This condition, in connection with that of uniform temperature, may be shown to be equivalent to (1) or (2). The difference of the values of ψ for two different states of the system which have the same temperature represents the work which would be expended in bringing the system from one state to the other by a reversible process and without change of temperature.

* Transactions of the Connecticut Academy of Arts and Sciences, vol. iii, pp. 108–248 and 343–524.

If the system is incapable of thermal changes, like the systems considered in theoretical mechanics, we may regard the entropy as having the constant value zero. Conditions (2) and (4) may then be written

$$\delta\varepsilon \geqq 0, \qquad \delta\psi \geqq 0,$$

and are obviously identical in signification, since in this case $\psi = \varepsilon$.

Conditions (2) and (4), as criteria of equilibrium, may therefore both be regarded as extensions of the criterion employed in ordinary statics to the more general case of a thermodynamic system. In fact, each of the quantities $-\varepsilon$ and $-\psi$ (relating to a system without sensible motion) may be regarded as a kind of force-function for the system,—the former as the force-function *for constant entropy*, (i. e., when only such states of the system are considered as have the same entropy,) and the latter as the force-function *for constant temperature*, (i. e., when only such states of the system are considered as have the same uniform temperature).

In the deduction of the particular conditions of equilibrium for any system, the general formula (4) has an evident advantage over (1) or (2) with respect to the brevity of the processes of reduction, since the limitation of constant temperature applies to every part of the system taken separately, and diminishes by one the number of independent variations in the state of these parts which we have to consider. Moreover, the transition from the systems considered in ordinary mechanics to thermodynamic systems is most naturally made by this formula, since it has always been customary to apply the principles of theoretical mechanics to real systems on the supposition (more or less distinctly conceived and expressed) that the temperature of the system remains constant, the mechanical properties of a thermodynamic system maintained at a constant temperature being such as might be imagined to belong to a purely mechanical system, and admitting of representation by a force-function, as follows directly from the fundamental laws of thermodynamics.

Notwithstanding these considerations, the author has preferred in general to use condition (2) as the criterion of equilibrium, believing that it would be useful to exhibit the conditions of equilibrium of thermodynamic systems in connection with those quantities which are most simple and most general in their definitions, and which appear most important in the general theory of such systems. The slightly different form in which the subject would develop itself, if condition (4) had been chosen as a point of departure instead of (2), is occasionally indicated.

Equilibrium of masses in contact.—The first problem to which the criterion is applied is the determination of the conditions of equilibrium for different masses in contact, when uninfluenced by gravity, electricity, distortion of the solid masses, or capillary tensions. The statement of the result is facilitated by the following definition.

If to any homogeneous mass in a state of hydrostatic stress we suppose an infinitesimal quantity of any substance to be added, the mass remaining homogeneous and its entropy and volume remaining unchanged, the increase of the energy of the mass divided by the quantity of the substance added is the *potential* for that substance in the mass considered.

In addition to equality of temperature and pressure in the masses in contact, it is necessary for equilibrium that the potential for every substance which is an independently variable component of any of the different masses shall have the same value in all of which it is such a component, so far as they are in contact with one another. But if a substance, without being an actual component of a certain mass in the given state of the system, is capable of being absorbed by it, it is sufficient if the value of the potential for that substance in that mass is not less than in any contiguous mass of which the substance is an actual component. We may regard these conditions as sufficient for equilibrium with respect to infinitesimal variations in the composition and thermodynamic state of the different masses in contact. There are certain other conditions which relate to the possible formation of masses entirely different in composition or state from any initially existing. These conditions are best regarded as determining the stability of the system, and will be mentioned under that head.

Anything which restricts the free movement of the component substances, or of the masses as such, may diminish the number of conditions which are necessary for equilibrium.

Equilibrium of osmotic forces.—If we suppose two fluid masses to be separated by a diaphragm which is permeable to some of the component substances and not to others, of the conditions of equilibrium which have just been mentioned, those will still subsist which relate to temperature and the potentials for the substances to which the diaphragm is permeable, but those relating to the potentials for the substances to which the diaphragm is impermeable will no longer be necessary. Whether the pressure must be the same in the two fluids will depend upon the rigidity of the diaphragm. Even when the diaphragm is permeable to all the components without restriction, equality of pressure in the two fluids is not always necessary for equilibrium.

Effect of gravity.—In a system subject to the action of gravity, the potential for each substance, instead of having a uniform value throughout the system, so far as the substance actually occurs as an independently variable component, will decrease uniformly with increasing height, the difference of its values at different levels being equal to the difference of level multiplied by the force of gravity.

Fundamental equations.—Let ε, η, v, t and p denote respectively the energy, entropy, volume, (absolute) temperature, and pressure of a homogeneous mass, which may be either fluid or solid, provided that it is subject only to hydrostatic pressures, and let m_1, m_2, . . . m_n denote the quantities of its independently variable components, and μ_1, μ_2, . . . μ_n the potentials for these components. It is easily shown that ε is a function of η, v, m_1, m_2, . . . m_n, and that the complete value of $d\varepsilon$ is given by the equation

$$d\varepsilon = t\,d\eta - p\,dv + \mu_1\,dm_1 + \mu_2\,dm_2 \ldots + \mu_n dm_n. \qquad (5)$$

Now if ε is known in terms of η, v, m_1, . . . m_n, we can obtain by differentiation t, p, μ_1, . . . μ_n in terms of the same variables. This will make $n + 3$ independent known relations between the $2n + 5$ variables, ε, η, v, m_1, m_2, . . . m_n, t, p, μ_1, μ_2, . . . μ_n. These are all that exist, for of these variables, $n + 2$ are evidently independent. Now upon these relations depend a very large class of the properties of the compound considered,—we may say in general, all its thermal, mechanical, and chemical properties, so far as *active tendencies* are concerned, in cases in which the form of the mass does not require consideration. A single equation from which all these relations may be deduced may be called a fundamental equation. An equation between ε, η, v, m_1, m_2, . . . m_n is a fundamental equation. But there are other equations which possess the same property.

If we suppose the quantity ψ to be determined for such a mass as we are considering by equation (3), we may obtain by differentiation and comparison with (5)

$$d\psi = -\eta\,dt - p\,dv + \mu_1\,dm_1 + m_2\,dm_2 \ldots + \mu_n\,dm_n. \qquad (6)$$

If, then, ψ is known as a function of t, v, m_1, m_2, . . . m_n, we can find η, p, μ_1, μ_2, . . . μ_n in terms of the same variables. If we then substitute for ψ in our original equation its value taken from equation (3) we shall have again $n + 3$ independent relations between the same $2n + 5$ variables as before.

Let

$$\zeta = \varepsilon - t\,\eta + p\,v, \qquad (7)$$

then, by (5),

$$d\zeta = -\eta\,dt + v\,dp + \mu_1\,dm_1 + \mu_2\,dm_2 \ldots + \mu_n\,dm_n. \qquad (8)$$

If, then, ζ is known as a function of $t, p, m_1, m_2, \ldots m_n$, we can find $\eta, v, \mu_1, \mu_2, \ldots \mu_n$ in terms of the same variables. By eliminating ζ, we may obtain again $n + 3$ independent relations between the same $2n + 5$ variables as at first.*

If we integrate (5), (6) and (8), supposing the quantity of the compound substance considered to vary from zero to any finite value, its nature and state remaining unchanged, we obtain

$$\varepsilon = t\eta - pv + \mu_1 m_1 + \mu_2 m_2 \ldots + \mu_n m_n \quad (9)$$

$$\psi = -pv + \mu_1 m_1 + \mu_2 m_2 \ldots + \mu_n m_n, \quad (10)$$

$$\zeta = \mu_1 m_1 + \mu_2 m_2 \ldots + \mu_n m_n. \quad (11)$$

If we differentiate (9) in the most general manner, and compare the result with (5), we obtain

$$-v\,dp + \eta\,dt + m_1\,d\mu_1 + m_2\,d\mu_2 \ldots + m_n\,d\mu_n = 0, \quad (12)$$

or

$$dp = \frac{\eta}{v}dt + \frac{m_1}{v}d\mu_1 + \frac{m_2}{v}d\mu_2 \ldots + \frac{m_n}{v}d\mu_n = 0. \quad (13)$$

Hence, there is a relation between the $n + 2$ quantities $t, p, \mu_1, \mu_2, \ldots \mu_n$, which, if known, will enable us to find in terms of these quantities all the ratios of the $n + 2$ quantities $\eta, v, m_1, m_2, \ldots m_n$. With (9), this will make $n + 3$ independent relations between the same $2n + 5$ variables as at first.

Any equation, therefore, between the quantities

$$\begin{array}{lccccc} & \varepsilon, & \eta, & v, & m_1, & m_2, \ldots m_n, \\ \text{or} & \psi, & t, & v, & m_1, & m_2, \ldots m_n, \\ \text{or} & \zeta, & t, & p, & m_1, & m_2, \ldots m_n, \\ \text{or} & & t, & p, & \mu_1, & \mu_2, \ldots \mu_n, \end{array}$$

is a fundamental equation, and any such is entirely equivalent to any other.

Coëxistent phases.—In considering the different homogeneous bodies which can be formed out of any set of component substances, it is convenient to have a term which shall refer solely to the composition and thermodynamic state of any such body without regard to its size or form. The word *phase* has been chosen for this purpose. Such bodies as differ in composition or state are called different phases of the matter considered, all

* The properties of the quantities $-\psi$ and $-\zeta$ regarded as functions of the temperature and volume, and temperature and pressure, respectively, the composition of the body being regarded as invariable, have been discussed by M. Massieu in a memoir entitled "Sur les fonctions caractéristiques des divers fluides et sur la théorie des vapeurs" (*Mém. Savants Étrang.*, t xxii.) A brief sketch of his method in a form slightly different from that ultimately adopted is given in *Comptes Rendus*, t. lxix, (1869) pp. 858 and 1057, and a report on his memoir by M. Bertrand in *Comptes Rendus*, t. lxxi. p. 257. M. Massieu appears to have been the first to solve the problem of representing all the properties of a body of invariable composition which are concerned in reversible processes by means of a single function.

bodies which differ only in size and form being regarded as different examples of the same phase. Phases which can exist together, the dividing surfaces being plain, in an equilibrium which does not depend upon passive resistances to change, are called *coëxistent.*

The number of independent variations of which a system of coëxistent phases is capable is $n+2-r$, where r denotes the number of phases, and n the number of independently variable components in the whole system. For the system of phases is completely specified by the temperature, the pressure, and the n potentials, and between these $n+2$ quantities there are r independent relations (one for each phase), which characterize the system of phases.

When the number of phases exceeds the number of components by unity, the system is capable of a single variation of phase. The pressure and all the potentials may be regarded as functions of the temperature. The determination of these functions depends upon the elimination of the proper quantities from the fundamental equations in p, t, μ_1, μ_2, etc., for the several members of the system. But without a knowledge of these fundamental equations, the values of the differential co-efficients such as $\frac{dp}{dt}$ may be expressed in terms of the entropies and volumes of the different bodies and the quantities of their several components. For this end we have only to eliminate the differentials of the potentials from the different equations of the form (12) relating to the different bodies. In the simplest case, when there is but one component, we obtain the well-known formula

$$\frac{dp}{dt}=\frac{\eta'-\eta''}{v'-v''}=\frac{Q}{t\,(v''-v')},$$

in which v', v'', η', η'', denote the volumes and entropies of a given quantity of the substance in the two phases, and Q the heat which it absorbs in passing from one phase to the other.

It is easily shown that if the temperature of two coëxistent phases of two components is maintained constant, the pressure is in general a maximum or minimum when the composition of the phases is identical. In like manner, if the pressure of the phases is maintained constant, the temperature is in general a maximum or minimum when the composition of the phases is identical. The series of simultaneous values of t and p for which the composition of two coëxistent phases is identical separates those simultaneous values of t and p for which no coëxistent phases are possible from those for which there are two pairs of coëxistent phases.

If the temperature of three coëxistent phases of three compo-

nents is maintained constant, the pressure is in general a maximum or minimum when the composition of one of the phases is such as can be produced by combining the other two. If the pressure is maintained constant, the temperature is in general a maximum or minimum when the same condition in regard to the composition of the phases is fulfilled.

Stability of fluids.—A criterion of the stability of a homogeneous fluid, or of a system of coëxistent fluid phases, is afforded by the expression

$$\varepsilon - t'\eta + p'v - \mu_1' m_1 - \mu_2' m_2 \ . \ . \ . \ - \mu_n' m_n \qquad (14)$$

in which the values of the accented letters are to be determined by the phase or system of phases of which the stability is in question, and the values of the unaccented letters by any other phase of the same components, the possible formation of which is in question. We may call the former constants, and the latter variables. Now if the value of the expression, thus determined, is always positive for any possible values of the variables, the phase or system of phases will be stable with respect to the formation of any new phases of its components. But if the expression is capable of a negative value, the phase or system is at least *practically* unstable. By this is meant that, although, strictly speaking, an infinitely small disturbance or change may not be sufficient to destroy the equilibrium, yet a very small change in the initial state will be sufficient to do so. The presence of a small portion of matter in a phase for which the above expression has a negative value will in general be sufficient to produce this result. In the case of a system of phases, it is of course supposed that their contiguity is such that the formation of the new phase does not involve any transportation of matter through finite distances.

The preceding criterion affords a convenient point of departure in the discussion of the stability of homogeneous fluids. Of the other forms in which the criterion may be expressed, the following is perhaps the most useful.

If the pressure of a fluid is greater than that of any other phase of its independent variable components which has the same temperature and potentials, the fluid is stable with respect to the formation of any other phase of these components; but if its pressure is not as great as that of some such phase, it will be practically unstable.

Stability of fluids with respect to continuous changes of phase.—In considering the changes which may take place in any mass, we have often to distinguish between infinitesimal changes in existing phases, and the formation of entirely new phases. A phase of a fluid may be stable with respect to the former kind of change, and unstable with respect to the latter. In this case, it may be capable of continued existence in virtue of proper-

ties which prevent the commencement of discontinuous changes. But a phase which is unstable with respect to continuous changes is evidently incapable of permanent existence on a large scale except in consequence of passive resistances to change. To obtain the conditions of stability with respect to continuous changes, we have only to limit the application of the variables in (14) to phases adjacent to the given phase. We obtain results of the following nature.

The stability of any phase with respect to continuous changes depends upon the same conditions with respect to the second and higher differential coëfficients of the density of energy regarded as a function of the density of entropy and the densities of the several components, which would make the density of energy a minimum, if the necessary conditions with respect to the first differential coëfficients were fulfilled.

Again, it is necessary and sufficient for the stability with respect to continuous changes of all the phases within any given limits, that within those limits the same conditions should be fulfilled with respect to the second and higher differential coëfficients of the pressure regarded as a function of the temperature and the several potentials, which would make the pressure a minimum, if the necessary conditions with respect to the first differential coëfficients were fulfilled

The equation of the limits of stability with respect to continuous changes may be written

$$\left(\frac{d\mu_n}{d\gamma_n}\right)_{t,\,\mu_1,\,\ldots\,\mu_{n-1}} = 0, \text{ or } \left(\frac{d^2p}{d\mu_n{}^2}\right)_{t,\,\mu_1,\,\ldots\,\mu_{n-1}} = \infty, \quad (15)$$

where γ_n denotes the density of the component specified or $m_n \div v$. It is in general immaterial to what component the suffix $_n$ is regarded as relating.

Critical phases.—The variations of two coëxistent phases are sometimes limited by the vanishing of the difference between them. Phases at which this occurs are called *critical phases.* A critical phase, like any other, is capable of $n+1$ independent variations, n denoting the number of independently variable components. But when subject to the condition of remaining a critical phase, it is capable of only $n-1$ independent variations. There are therefore two independent equations which characterize critical phases. These may be written

$$\left(\frac{d\mu_n}{d\gamma_n}\right)_{t,\,\mu_1,\,\ldots\,\mu_{n-1}} = 0, \left(\frac{d^2\mu_n}{d\gamma_n{}^2}\right)_{t,\,\mu_1,\,\ldots\,\mu_{n-1}} = 0. \quad (16)$$

It will be observed that the first of these equations is identical with the equation of the limit of stability with respect to continuous changes. In fact, stable critical phases are situated at that limit. They are also situated at the limit of stability with

respect to discontinuous changes. These limits are in general distinct, but touch each other at critical phases.

Geometrical illustrations.—In an earlier paper,* the author has described a method of representing the thermodynamic properties of substances of invariable composition by means of surfaces. The volume, entropy, and energy of a constant quantity of the substance are represented by rectangular coördinates. This method corresponds to the first kind of fundamental equation described above. Any other kind of fundamental equation for a substance of invariable composition will suggest an analogous geometrical method. In the present paper, the method in which the coördinates represent temperature, pressure, and the potential, is briefly considered. But when the composition of the body is variable, the fundamental equation cannot be completely represented by any surface or finite number of surfaces. In the case of three components, if we regard the temperature and pressure as constant, as well as the total quantity of matter, the relations between ζ, m_1, m_2, m_3 may be represented by a surface in which the distances of a point from the three sides of a triangular prism represent the quantities m_1, m_2, m_3, and the distance of the point from the base of the prism represents the quantity ζ. In the case of two components, analogous relations may be represented by a plane curve. Such methods are especially useful for illustrating the combinations and separations of the components, and the changes in states of aggregation, which take place when the substances are exposed in varying proportions to the temperature and pressure considered.

Fundamental equations of ideal gases and gas-mixtures.—From the physical properties which we attribute to ideal gases, it is easy to deduce their fundamental equations. The fundamental equation in ε, η, v, and m for an ideal gas is

$$c \log \frac{\varepsilon - \mathrm{E}m}{cm} = \frac{\eta}{m} - \mathrm{H} + a \log \frac{m}{v}: \tag{17}$$

that in ψ, t, v, and m is

$$\psi = \mathrm{E}m + mt\left(c - \mathrm{H} - c \log t + a \log \frac{m}{v}\right): \tag{18}$$

that in p, t, and μ is

$$p = a e^{\frac{\mathrm{H}-c-a}{a}} t^{\frac{c+a}{a}} e^{\frac{\mu - \mathrm{E}}{at}}, \tag{19}$$

where e denotes the base of the Naperian system of logarithms. As for the other constants, c denotes the specific heat of the

* Transactions of the Connecticut Academy, vol. ii, part 2.

gas at constant volume, a denotes the constant value of $pv \div mt$, E and H depend upon the zeros of energy and entropy. The two last equations may be abbreviated by the use of different constants. The properties of fundamental equations mentioned above may easily be verified in each case by differentiation.

The law of Dalton respecting a mixture of different gases affords a point of departure for the discussion of such mixtures and the establishment of their fundamental equations. It is found convenient to give the law the following form:

The pressure in a mixture of different gases is equal to the sum of the pressures of the different gases as existing each by itself at the same temperature and with the same value of its potential.

A mixture of ideal gases which satisfies this law is called an *ideal gas-mixture.* Its fundamental equation in p, t, μ_1, μ_2, etc. is evidently of the form

$$p = \Sigma_1 \left(a_1 e^{\frac{H_1 - c_1 - a_1}{a_1}} t^{\frac{c_1 + a_1}{a_1}} e^{\frac{\mu_1 - E_1}{a_1 t}} \right), \qquad (20)$$

where Σ_1 denotes summation with respect to the different components of the mixture. From this may be deduced other fundamental equations for ideal gas-mixtures. That in ψ, t, v, m_1, m_2, etc. is

$$\psi = \Sigma_1 \left(E_1 m_1 + m_1 t \left(c_1 - H_1 - c_1 \log t + a_1 \log \frac{m_1}{v} \right) \right). \qquad (21)$$

Phases of dissipated energy of ideal gas-mixtures.—When the proximate components of a gas-mixture are so related that some of them can be formed out of others, although not necessarily in the gas-mixture itself at the temperatures considered, there are certain phases of the gas-mixture which deserve especial attention. These are the *phases of dissipated energy*, i. e., those phases in which the energy of the mass has the least value consistent with its entropy and volume. An atmosphere of such a phase could not furnish a source of mechanical power to any machine or chemical engine working within it, as other phases of the same matter might do. Nor can such phases be affected by any catalytic agent. A *perfect catalytic agent* would reduce any other phase of the gas-mixture to a phase of dissipated energy. The condition which will make the energy a minimum is that the potentials for the proximate components shall satisfy an equation similar to that which expresses the relation between the units of weight of these components. For example, if the components were hydrogen, oxygen and water, since one gram of hydrogen with eight grams of oxygen are chemically equivalent to nine grams of water, the potentials for these substances in a phase of dissipated energy must satisfy the relation

$$\mu_H + 8\mu_O = 9\mu_W.$$

Gas-mixtures with convertible components.—The theory of the phases of dissipated energy of an ideal gas-mixture derives an especial interest from its possible application to the case of those gas-mixtures in which the chemical composition and resolution of the components can take place in the gas-mixture itself, and actually does take place, so that the quantities of the proximate components are entirely determined by the quantities of a smaller number of ultimate components, with the temperature and pressure. These may be called *gas-mixtues with convertible components.* If the general laws of *ideal* gas-mixtures apply in any such case, it may easily be shown that the phases of dissipated energy are the only phases which can exist. We can form a fundamental equation which shall relate solely to these phases. For this end, we first form the equation in p, t, μ_1, μ_2, etc. for the gas-mixture, regarding its proximate components as *not* convertible. This equation will contain a potential for every proximate component of the gas-mixture. We then eliminate one (or more) of these potentials by means of the relations which exist between them in virtue of the convertibility of the components to which they relate, leaving the potentials which relate to those substances which naturally express the ultimate composition of the gas-mixture.

The validity of the results thus obtained depends upon the applicability of the laws of ideal gas-mixtures to cases in which chemical action takes place. Some of these laws are generally regarded as capable of such application, others are not so regarded. But it may be shown that in the very important case in which the components of a gas are convertible at certain temperatures, and not at others, the theory proposed may be established without other assumptions than such as are generally admitted.

It is, however, only by experiments upon gas-mixtures with convertible components, that the validity of any theory concerning them can be satisfactorily established.

The vapor of the peroxide of nitrogen appears to be a mixture of two different vapors, of one of which the molecular formula is double that of the other. If we suppose that the vapor conforms to the laws of an ideal gas-mixture in a state of dissipated energy, we may obtain an equation between the temperature, pressure, and density of the vapor, which exhibits a somewhat striking agreement with the results of experiment.

Equilibrium of stressed solids.—The second paper commences with a discussion of the conditions of internal and external equilibrium for solids in contact with fluids with regard to all possible states of strain of the solids. These conditions are deduced by analytical processes from the general condition of

equilibrium (2). The condition of equilibrium which relates to the dissolving of the solid at a surface where it meets a fluid may be expressed by the equation

$$\mu_1 = \frac{\varepsilon - t\eta + pv}{m}, \tag{22}$$

where ε, η, v, and m_1 denote respectively the energy, entropy, volume, and mass of the solid, if it is homogeneous in nature and state of strain,—otherwise, of any small portion which may be treated as thus homogeneous,—μ_1 the potential in the fluid for the substance of which the solid consists, p the pressure in the fluid and therefore one of the principal pressures in the solid, and t the temperature. It will be observed that when the pressure in the solid is isotropic, the second member of this equation will represent the potential in the solid for the substance of which it consists [see (9)], and the condition reduces to the equality of the potential in the two masses, just as if it were a case of two fluids. But if the stresses in the solid are not isotropic, the value of the second member of the equation is not entirely determined by the nature and state of the solid, but has in general three different values (for the same solid at the same temperature, and in the same state of strain) corresponding to the three principal pressures in the solid. If a solid in the form of a right parallelopiped is subject to different pressures on its three pairs of opposite sides by fluids in which it is soluble, it is in general necessary for equilibrium that the composition of the fluids shall be different.

The *fundamental equations* which have been described above are limited, in their application to solids, to the case in which the stresses in the solid are isotropic. An example of a more general form of fundamental equation for a solid, is afforded by an equation between the energy and entropy of a given quantity of the solid, and the quantities which express its state of strain, or by an equation between ψ [see (3)] as determined for a given quantity of the solid, the temperature, and the quantities which express the state of strain.

Capillarity.—The solution of the problems which precede may be regarded as a first approximation, in which the peculiar state of thermodynamic equilibrium about the surfaces of discontinuity is neglected. To take account of the condition of things at these surfaces, the following method is used. Let us suppose that two homogeneous fluid masses are separated by a surface of discontinuity, i. e., by a very thin non-homogeneous film. Now we may imagine a state of things in which each of the homogeneous masses extends without variation of the densities of its several components, or of the densities of energy and entropy, quite up to a geometrical surface (to be called the divid-

ing surface) at which the masses meet. We may suppose this surface to be sensibly coincident with the physical surface of discontinuity. Now if we compare the actual state of things with the supposed state, there will be in the former in the vicinity of the surface a certain (positive or negative) excess of energy, of entropy, and of each of the component substances. These quantities are denoted by ε^s, η^s, m_1^s, m_2^s, etc. and are treated as belonging to the surface. The ^{s} is used simply as a distinguishing mark, and must not be taken for an algebraic exponent.

It is shown that the conditions of equilibrium already obtained relating to the temperature and the potentials of the homogeneous masses, are not affected by the surfaces of discontinuity, and that the complete value of $d\varepsilon^s$ is given by the equation

$$\delta\varepsilon^s = t\,\delta\eta^s + \sigma\,\delta s + \mu_1\,\delta m_1^s + \mu_2\,\delta m_2^s + \text{etc.} \qquad (23)$$

in which s denotes the area of the surface considered, t the temperature, μ_1, μ_2, etc. the potentials for the various components in the adjacent masses. It may be, however, that some of the components are found only at the surface of discontinuity, in which case the letter μ with the suffix relating to such a substance denotes, as the equation shows, the rate of increase of energy at the surface per unit of the substance added, when the entropy, the area of the surface, and the quantities of the other components are unchanged. The quantity σ we may regard as defined by the equation itself, or by the following, which is obtained by integration:

$$\varepsilon^s = t\,\eta^s + \sigma\,s + \mu_1 m_1^s + \mu_2 m_2^s + \text{etc.} \qquad (24)$$

There are terms relating to variations of the curvatures of the surface which might be added, but it is shown that we can give the dividing surface such a position as to make these terms vanish, and it is found convenient to regard its position as thus determined. It is always sensibly coincident with the physical surface of discontinuity. (Yet in treating of plane surfaces, this supposition in regard to the position of the dividing surface is unnecessary, and it is sometimes convenient to suppose that its position is determined by other considerations.)

With the aid of (23), the remaining condition of equilibrium for contiguous homogeneous masses is found, viz:

$$\sigma\,(c_1 + c_2) = p' - p'', \qquad (25)$$

where p', p'' denote the pressures in the two masses, and c_1, c_2 the principal curvatures of the surface. Since this equation has the same form as if a tension equal to σ resided at the surface, the quantity σ is called (as is usual) the *superficial tension*, and the dividing surface in the particular position above mentioned is called the *surface of tension*.

By differentiation of (24) and comparison with (23), we obtain

$$d\sigma = -\eta_s dt - \Gamma_1 d\mu_1 - \Gamma_2 d\mu_2 - \text{etc.}, \tag{26}$$

where η_s, Γ_1, Γ_2, etc. are written for $\frac{\eta^s}{s}$, $\frac{m_1^s}{s}$, $\frac{m_2^s}{s}$, etc., and denote the superficial densities of entropy and of the various substances. We may regard σ as a function of t, μ_1, μ_2, etc., from which if known η_s, Γ_1, Γ_2, etc. may be determined in terms of the same variables. An equation between σ, t, μ_1, μ_2, etc. may therefore be called a *fundamental equation for the surface of discontinuity.* The same may be said of an equation between ε^s, η^s, s, m_1^s, m_2^s, etc.

It is necessary for the stability of a surface of discontinuity that its tension shall be as small as that of any other surface which can exist between the same homogeneous masses with the same temperature and potentials. Beside this condition, which relates to the nature of the surface of discontinuity, there are other conditions of stability, which relate to the possible motion of such surfaces. One of these is that the tension shall be positive. The others are of a less simple nature, depending upon the extent and form of the surface of discontinuity, and in general upon the whole system of which it is a part. The most simple case of a system with a surface of discontinuity is that of two coëxistent phases separated by a spherical surface, the outer mass being of indefinite extent. When the interior mass and the surface of discontinuity are formed entirely of substances which are components of the surrounding mass, the equilibrium is always unstable; in other cases, the equilibrium may be stable. Thus, the equilibrium of a drop of water in an atmosphere of vapor is unstable, but may be made stable by the addition of a little salt. The analytical conditions which determine the stability or instability of the system are easily found, when the temperature and potentials of the system are regarded as known, as well as the fundamental equations for the interior mass and the surface of discontinuity.

The study of surfaces of discontinuity throws considerable light upon the subject of the stability of such phases of fluids as have a less pressure than other phases of the same components with the same temperature and potentials. Let the pressure of the phase of which the stability is in question be denoted by p', and that of the other phase of the same temperature and potentials by p''. A spherical mass of the second phase and of a radius determined by the equation

$$2\sigma = (p'' - p')\, r, \tag{27}$$

would be in equilibrium with a surrounding mass of the first phase. This equilibrium, as we have just seen, is instable, when the surrounding mass is indefinitely extended. A spherical

mass a little larger would tend to increase indefinitely. The work required to form such a spherical mass, by a reversible process, in the interior of an infinite mass of the other phase, is given by the equation

$$W = \sigma s - (p'' - p')\, v''. \tag{28}$$

The term σs represents the work spent in forming the surface, and the term $(p'' - p')\, v''$ the work gained in forming the interior mass. The second of these quantities is always equal to two-thirds of the first. The value of W is therefore positive, and the phase is in strictness stable, the quantity W affording a kind of measure of its stability. We may easily express the value of W in a form which does not involve any geometrical magnitudes, viz:

$$W = \frac{16\,\pi\,\sigma^3}{3(p'' - p')^2}, \tag{29}$$

where p'', p' and σ may be regarded as functions of the temperature and potentials. It will be seen that the stability, thus measured, is infinite for an infinitesimal difference of pressures, but decreases very rapidly as the difference of pressures increases. These conclusions are all, however, practically limited to the case in which the value of r, as determined by equation (27) is of sensible magnitude.

With respect to the somewhat similar problem of the stability of the surface of contact of two phases with respect to the formation of a new phase, the following results are obtained. Let the phases (supposed to have the same temperature and potentials) be denoted by A, B, and C; their pressures by p_A, p_B and p_C; and the tensions of the three possible surfaces σ_{AB}, σ_{BC}, σ_{AC}. If p_C is less than

$$\frac{\sigma_{BC}\, p_A + \sigma_{AC}\, p_B}{\sigma_{BC} + \sigma_{AC}},$$

there will be no tendency toward the formation of the new phase at the surface between A and B. If the temperature or potentials are now varied until p_C is equal to the above expression, there are two cases to be distinguished. The tension σ_{AB} will be either equal to $\sigma_{AC} + \sigma_{BC}$ or less. (A greater value could only relate to an unstable and therefore unusual surface.) If $\sigma_{AB} = \sigma_{AC} + \sigma_{BC}$, a farther variation of the temperature or potentials, making p_C greater than the above expression, would cause the phase C to be formed at the surface between A and B. But if $\sigma_{AB} < \sigma_{AC} + \sigma_{BC}$, the surface between A and B would remain stable, but with rapidly diminishing stability, after p_C has passed the limit mentioned.

The conditions of stability for a line where several surfaces of discontinuity meet, with respect to the possible formation of

a new surface, are capable of a very simple expression. If the surfaces A-B, B-C, C-D, D-A, separating the masses A, B, C, D, meet along a line, it is necessary for equilibrium that their tensions and directions at any point of the line should be such that a quadrilateral $\alpha, \beta, \gamma, \delta$ may be formed with sides representing in direction and length the normals and tensions of the successive surfaces. For the stability of the system with reference to the possible formation of surfaces between A and C, or between B and D, it is farther necessary that the tensions σ_{AC} and σ_{BD} should be greater than the diagonals $\alpha\gamma$ and $\beta\delta$ respectively. The conditions of stability are entirely analogous in the case of a greater number of surfaces. For the conditions of stability relating to the formation of a new phase at a line in which three surfaces of discontinuity meet, or at a point where four different phases meet, the reader is referred to the original paper.

Liquid films.—When a fluid exists in the form of a very thin film between other fluids, the great inequality of its extension in different directions will give rise to certain peculiar properties, even when its thickness is sufficient for its interior to have the properties of matter in mass. The most important case is where the film is liquid and the contiguous fluids are gaseous. If we imagine the film to be divided into elements of the same order of magnitude as its thickness, each element extending through the film from side to side, it is evident that far less time will in general be required for the attainment of approximate equilibrium between the different parts of any such element and the contiguous gases than for the attainment of equilibrium between all the different elements of the film.

There will accordingly be a time, commencing shortly after the formation of the film, in which its separate elements may be regarded as satisfying the conditions of internal equilibrium, and of equilibrium with the contiguous gases, while they may not satisfy all the conditions of equilibrium with each other. It is when the changes due to this want of complete equilibrium take place so slowly that the film appears to be at rest, except so far as it accommodates itself to any change in the external conditions to which it is subjected, that the characteristic properties of the film are most striking and most sharply defined. It is from this point of view that these bodies are discussed. They are regarded as satisfying a certain well-defined class of conditions of equilibrium, but as not satisfying at all certain other conditions which would be necessary for complete equilibrium, in consequence of which they are subject to gradual changes, which ultimately determine their rupture.

The elasticity of a film (i. e., the increase of its tension when extended,) is easily accounted for. It follows from the general

relations given above that, when a film has more than one component, those components which diminish the tension will be found in greater proportion on the surfaces. When the film is extended, there will not be enough of these substances to keep up the same volume- and surface-densities as before, and the deficiency will cause a certain increase of tension. It does not follow that a thinner film has always a greater tension than a thicker formed of the same liquid. When the phases within the films as well as without are the same, and the surfaces of the films are also the same, there will be no difference of tension. Nor will the tension of the same film be altered, if a part of the interior drains away in the course of time, without affecting the surfaces. If the thickness of the film is reduced by evaporation, its tension may be either increased or diminished, according to the relative volatility of its different components.

Let us now suppose that the thickness of the film is reduced until the limit is reached at which the interior ceases to have the properties of matter in mass. The elasticity of the film, which determines its stability with respect to extension and contraction, does not vanish at this limit. But a certain kind of instability will generally arise, in virtue of which inequalities in the thickness of the film will tend to increase through currents in the interior of the film. This probably leads to the destruction of the film, in the case of most liquids. In a film of soap-water, the kind of instability described seems to be manifested in the breaking out of the black spots. But the sudden diminution in thickness which takes place in parts of the film is arrested by some unknown cause, possibly by viscous or gelatinous properties, so that the rupture of the film does not necessarily follow.

Electromotive force.—The conditions of equilibrium may be modified by electromotive force. Of such cases a galvanic or electrolytic cell may be regarded as the type. With respect to the potentials for the ions and the electrical potential the following relation may be noticed:

When all the conditions of equilibrium are fulfilled in a galvanic or electrolytic cell, the electromotive force is equal to the difference in the values of the potential for any ion at the surfaces of the electrodes multiplied by the electro-chemical equivalent of that ion, the greater potential of an anion being at the same electrode as the greater electrical potential, and the reverse being true of a cation.

The relation which exists between the electromotive force of a *perfect electro-chemical apparatus* (i. e., a galvanic or electrolytic cell which satisfies the condition of reversibility,) and the changes in the cell which accompany the passage of electricity, may be expressed by the equation

$$d\varepsilon = (\mathrm{V}' - \mathrm{V}'')\, de + t\, d\eta + d\,\mathrm{W}_G + d\mathrm{W}_P, \qquad (30)$$

in which $d\varepsilon$ denotes the increment of the intrinsic energy in the apparatus, $d\eta$ the increment of entropy, de the quantity of electricity which passes through it, V′ and V″ the electrical potentials in pieces of the same kind of metal connected with the anode and cathode respectively, $d\mathrm{W_G}$ the work done by gravity, and $d\mathrm{W_P}$ the work done by the pressures which act on the external surface of the apparatus. The term $d\mathrm{W_G}$ may generally be neglected. The same is true of $d\mathrm{W_P}$, when gases are not concerned. If no heat is supplied or withdrawn the term $t\,d\eta$ will vanish. But in the calculation of electromotive forces, which is the most important application of the equation, it is convenient and customary to suppose that the temperature is maintained constant. Now this term $t\,d\eta$, which represents the heat absorbed by the cell, is frequently neglected in the consideration of cells of which the temperature is supposed to remain constant. In other words, it is frequently assumed that neither heat or cold is produced by the passage of an electrical current through a perfect electro-chemical apparatus (except that heat which may be indefinitely diminished by increasing the time in which a given quantity of electricity passes), unless it be by processes of a secondary nature, which are not immediately or necessarily connected with the process of electrolysis.

That this assumption is incorrect is shown by the electromotive force of a gas battery charged with hydrogen and nitrogen, by the currents caused by differences in the concentration of the electrolyte, by electrodes of zinc and mercury in a solution of sulphate of zinc, by *a priori* considerations based on the phenomena exhibited in the direct combination of the elements of water or of hydrochloric acid, by the absorption of heat which M. Favre has in many cases observed in a galvanic or electrolytic cell, and by the fact that the solid or liquid state of an electrode (at its temperature of fusion) does not affect the electromotive force.

ART. LIII.—*On an Anatomical Peculiarity by which Crania of the Mound builders may be distinguished from those of the Modern Indians;** by W. J. McGEE, Farley, Iowa.

THE difficulty of determining whether a skull from a mound belonged to a modern Indian or to an individual of the mysterious race which erected the mounds of the Mississippi Valley is well known; and so complex is the problem that only an anatomist of long experience and tried skill can satisfactorily solve it. Even then it frequently happens that "doctors

* Read before the American Association for the Advancement of Science at St. Louis.

disagree;" as when Col. Foster, at one time president of this Association, declared that the only cranium figured by Squier and Davis in their great work on the "Ancient Monuments of the Mississippi Valley" as representative of the cranial structure of the Mound-builders, did not belong to that race at all. Any observations throwing light on the question of the relations of these crania will therefore be of practical value.

The writer has made a pretty thorough study of the archæology of northeastern Iowa, and has examined several skulls unearthed in that region, as well as some from Wisconsin, Illinois and Kentucky. The total number of Mound-builders' crania examined will not, however, exceed fifty or seventy-five; and a part of these were fragmentary. Hence the observations cannot be considered to afford a perfectly reliable guide in the determination of crania, and too great weight should not be attached to them until verified by authentic cases of a similar nature from other quarters. At present they have but a provisional significance. The structural peculiarity which has been found to be a more trustworthy distinguishing feature than differences in the capacity or general contour of the skulls, relative length and breadth, thickness of walls, or condition and state of preservation of the bone, is the greater relative size of the posterior molars or "wisdom teeth" in both maxillaries of the Mound-builders' crania than in those of the recent red race. Measurements have not been made to illustrate this difference in relative size, principally because the preparation of this paper was occasioned by the discussion following the reading on yesterday morning of an archæological paper in this section, since which time specimens from which dimensions could be taken have not been accessible.

Aside from the simple difference in relative size of the posterior and anterior molars, it seems that the "wisdom teeth" were earlier developed in the individuals of the Mound-building race than in either the Indian or the white man. It is well known that the posterior molars do not usually appear in civilized man until near maturity. Exceptions to this rule are not infrequent but they may be put down as cases of reversion. That this is warrantable will be more obvious further on. Again, these teeth are rarely so fully developed during the lifetime of the individual, in the white races, as to have their grinding surfaces worn down equally with the anterior molars. They therefore partake to some extent of the nature of rudimentary organs. In crania from the mounds, which were from young individuals as attested by the imperfect anchylosis of the sutures permitting fractures to easily occur along these lines, sometimes even the complete decomposition of the symphyses supervened, these

teeth have been found fully developed and the grinding surface nearly or quite as far worn down as in their anterior neighbors. In more mature crania the surface of the posterior molar is usually the largest and apparently the most worn down. Hence in the Mound-builder this tooth was not by any means rudimentary, but was a useful organ throughout nearly the whole of the lifetime of its possessor.

The corresponding tooth of the modern Indian occupies—if the Indian crania examined were typical, as they seemed to be—an intermediate stage in development between that of the Mound-builder on the one hand and that of the Caucassian on the other. As to the period at which the tooth makes its appearance and when it reaches its full development, the writer has been able to learn nothing thus far. This point seems to have escaped the notice of ethnologists heretofore. The difference in relative size and in the comparative maturity of these teeth is sufficient, however, in nearly all the specimens examined, to allow of their ready determination. Nevertheless this rule could not be indiscriminately applied, as due allowance must be made for differences in age, etc., of the individual; but with care and judgment the writer is convinced that it is competent.

The greater development of the posterior molars seems to be common to the lower and earlier races. This peculiarity has been observed in several of the fossil skulls of paleolithic man exhumed in Europe, as in the jaw-bone from the cave of Naulette, Belgium, in which, as reported by the Belgian geologists, the molar teeth increased in size backward. Dr. E. Lambert, of Brussels, has recently made an extensive collection of crania of various races, and has found that the posterior molar is relatively larger, not only in the red but in the black races than in the Caucassian. The dentation of the yellow races, however, corresponds more nearly with that of the white.* So far as known to the writer Dr. Lambert has not noted the period of development of these teeth in any of the races.

This morphological variation in the different stocks of mankind is probably a concomitant of the principle of cephalization if not directly coördinated therewith. It has been shown by Prof. Dana that cephalization is "a fundamental principle in the development of the system of animal life,"† and that there has been an increase in cerebral volume in many if not all mammals since early cenozoic time; and Professor Marsh has shown that this tendency is manifested in a striking degree

* Scientific American, vol. xxxviii, p. 98.

† This Journal, III, vol. xii, October, 1876, p. 245. References to Professor Marsh's papers are given in this memoir.

in the Eocene Dinoceras and Coryphodon, in the Miocene Brontotherium, and in the Pliocene Mastodon. But the researches of Marsh, Leidy, Cope, Hayden and others, in the Cretaceous and Tertiary beds of the western territories have shown us that there is a concurrent tendency toward a decrease in size of the posterior and increase in size of the anterior molars observable in perhaps any class of mammals which we may examine. The tendency is just as plainly marked as that toward increase in cranial capacity or toward compactness and abbreviation of the anterior organs,—indeed it is undoubtedly correlated with the shortening and compacting of the jaws. And it is probable that the degree of development of any mammal, as the horse or pig, can be just as readily and reliably measured by the relative size of its molars as by the size of its brain-case or by the presence or absence of certain bones of manus or pes. Casual statements to the effect that the relative size of the posterior molar varies inversely as the volume of the brain have indeed been met with, but no critical discussion of the true significance of such relations; and their practical bearing on the work of the determination of native American crania seems to have been wholly overlooked, as it certainly was in the discussion of yesterday.

Planters' Hotel, St. Louis, Aug. 23, 1878.

ART. LIV.—*On the Limits of Hypotheses regarding the Properties of the Matter composing the Interior of the Earth;* by HENRY HENNESSY, F.R.S, Professor of Applied Mathematics in the Royal College of Science for Ireland.*

1. FROM direct observation we are able to obtain only a very moderate knowledge of the materials existing below the solid crust of the earth. The depth to which we can penetrate by mining and boring operations into this crust is comparatively insignificant; and these operations give us little knowledge of the earth's interior in comparison with what is afforded by the outpourings of volcanoes. Two hundred active volcanoes are said to still exist, while geologists have established that many thousands of such deep apertures in the earth's crust have existed during remote epochs of its physical history. The source or sources of supply for all these volcanoes have poured out a predominating mass of matter in a state of liquidity from fusion. Evidence is thus furnished that matter in a state of fluidity exists very widely distributed through the earth. The

* From the Phil. Mag. for Oct., 1878. Read before the Mathematical and Physical Section of the British Association for the Advancement of Science, Dublin, August, 1878.

supposition that this fluid fills the whole interior, and that the solid crust is a mere exterior envelope, is usually designated as the hypothesis of internal fluidity. From this hypothesis mechanical and physical results of primary importance in terrestrial physics may be deduced.

Newton, Clairaut, Laplace, Airy, and other illustrious mathematicians have used an extension of this hypothesis in discussing the earth's figure. They supposed the particles composing the earth to retain the same positions after solidification as that which they held before it. I ventured, for the first time, to discard the latter portion of the hypothesis as useless and contrary to physical laws. I now venture to say that, in framing any hypotheses as to the physical character of the matter of the earth, we should not affix any property to the supposed matter which is opposed to the properties observed in similar kinds of matter coming under our direct observation. Observation has disclosed that liquids are in general viscid, and that they possess what has been designated internal friction in a high degree.* Observation has recently shown that among the three states of matter (gaseous, liquid and solid) a law of continuity exists. Observation also discloses that gases and vapors are, of all forms of matter, the most compressible, that liquids are much less compressible, and that solids are still less compressible. Thus, for instance, water is about fourteen times more compressible than copper or brass.

2. If these general comparative properties of liquids and solids are admitted, it follows that in the hypotheses regarding the earth's internal structure we should most carefully guard against any assumption directly in contradiction to such properties. By assuming that the earth contained a fluid totally devoid of viscidity and internal friction, the late Mr. Hopkins attempted to prove the earth's entire solidity. He only proved that it did not contain any of this imaginary fluid; but he by no means proved the non-existence of a liquid possessing the properties of viscidity and internal friction common to all liquids. In the Comptes Rendus of the Academy of Sciences of Paris for 1871 is a paper in which I have given a *résumé* of the arguments against Mr. Hopkins's conclusions as to the earth's complete solidity; and in the subsequent discussions my priority on this matter seems to have been fairly and honorably acknowledged.† In a recent admirable work on

* As having a special connection with this subject, see a Report by the Author on Experiments on the influence of the molecular condition of fluids, on their motion when in rotation and in contact with solids (Proceedings of the Royal Irish Academy, 2nd series, vol. iii, p. 55).

† "Remarques à propos d'une Communication de M. Delaunay sur les résultats fournis par l'Astronomie concernant l'épaisseur de la croûte solide du Globe," *Comptes Rendus de l'Inst. France*, Mars 6, 1871, p. 250.

Geology, Pfaff's Grundriss der Geologie, the author gives a brief account of the bearing of astronomical and mathematical investigations on the internal structure of the earth; and he very justly says that the results of observation compel us to regard the earth as for the most part fluid, in order to bring these results into harmony with calculation. Professor Pfaff attributes this conclusion to Hopkins, whereas it is precisely that which I had long since enunciated, and is entirely opposed to the views of Mr. Hopkins. More recently Sir William Thomson and Mr. Darwin have investigated the tidal action of an internal fluid nucleus upon its containing solid shell. They have both supposed the liquid to be totally incompressible, and the containing vessel to be elastic and therefore compressible. They have thus given the liquid a property which no liquid in existence possesses, and the solid a property which solids possess in a much less degree than liquids. Their hypothesis is thus totally inadmissible as a part of the problem of inquiry into the earth's structure. I at once admit that a thin elastic spheroidal envelope filled with incompressible liquid and subjected to the attraction of exterior bodies would present periodical deformations, owing to tidal action far surpassing the tides of the ocean. But I do not admit that such impossible substances can represent the materials of the earth. My hypothesis is that the liquid interior matter, instead of being incompressible, is, like all liquids we observe, relatively far more compressible than its solid envelope. A highly compressible liquid contained in a very much less-compressible shell would be a hypothesis more in harmony with physical observation. The tidal phenomena of a compressible fluid, it is easy to see, would be very different from those of an incompressible fluid. The work done by the action of certain disturbing bodies in the strata of compressible fluid would partly result in causing variations of density, instead of producing tidal waves of great magnitude. This has been already shown in the Mécanique Céleste by Laplace, in discussing the tides of the atmosphere. Theory shows that the atmospheric tides should be nearly insensible, notwithstanding the great depth of the atmospheric column, because the work done in the atmosphere is very different from what is performed in the less-compressible water of the ocean. Observation has fully verified this result.

3. It is admitted that the earth's density increases from its surface toward its center. If its interior is occupied by a compressible fluid, the law of density of this fluid would result from the compression of its own strata; just as the law of density of the atmosphere is produced by the pressure of the upper atmospheric layers upon those below. But instead of supposing the interior of the earth to be filled by a fluid thus con-

forming to the observed properties of fluids, both Sir William Thomson and Mr. Darwin have applied their great powers as accomplished mathematicians to the tides of an incompressible and homogeneous spheroid, such as I admit to have no real existence whatsoever.

4. The labor bestowed on the problem investigated could scarcely be considered at all necessary or fruitful, except as affording an admirable illustration of the results flowing from the employment of hypotheses framed in direct contradiction to the fundamental conditions to which every truly philosophical hypothesis must conform. It is scarcely necessary to add, that the conclusions of Mr. Darwin, as well as those of Sir William Thomson, cannot be considered as having invalidated the carefully framed hypothesis that the earth consists of a solid crust physically similar to the rocks we are enabled to observe, and a contained spheroid of liquids and physically similar to the liquid rock poured out by volcanic openings.

5. It is with much satisfaction that I can trace a gradual growth of more correct physical views on the questions referred to in this paper. In Nature, vol. v, p. 288, a paper appeared in which I ventured to criticise Sir William Thomson's memoir on the Rigidity of the Earth, in the Philosophical Transactions. At the Meeting of the British Association in Glasgow, Sir William Thomson acknowledged the invalidity of many of his arguments, and requested his audience to draw their pens through paragraphs from 23 to 31 in his paper. These paragraphs contain statements and reasonings which I had already shown to be inconclusive in the paper which has just been quoted.

In Mr. Darwin's paper, recently communicated to the British Association, he admits that in discussing the precessional and tidal phenomena of a viscous liquid, the supposition of an elastic spheroid would lead to *very different* results—that is to say, results very different from those deduced by himself and Sir William Thomson regarding the earth's structure, and which the followers of the late Sir Charles Lyell have frequently assumed to be established. Thus the late Mr. Poulett Scrope appears to have referred to the bearing of the mathematical investigations alluded to, on what he calls "the sensational idea" of an internal incandescent fluid beneath the solid crust of the earth. He forgot that an idea may not be the less true because it is sensational. The idea of antipodes was at one time regarded as highly sensational. Those who witness a great earthquake or volcanic eruption are usually impressed with the sensational character of the phenomena.

6. A traveller who was in Portugal more than forty years since, met a woman over one hundred years of age, and asked

her if she recollected the great earthquake of Lisbon. She replied, that it was the event of all others in her long life which she ought to vividly recollect, on account of its impressive sensations. History also records the sensational character of the destruction of Pompeii. If Mr. Scrope's innuendo regarding the internal fluidity of the earth as "a sensational hypothesis" has any value, we should regard the events referred to as highly improbable; yet they have been as well authenticated as the most positive facts in science, and no person has ever expressed the smallest shadow of a doubt as to their occurrence.

ART. LV.—*Discoveries in Western Caves;* by Rev. HORACE C. HOVEY, M.A.

THE following notes are selected from a large mass of descriptive material, collected by the writer during recent underground explorations in some of the States of the Mississippi Valley.

1. *Silurian Caves.*—Especial attention was paid to these caves in view of the "grave doubts" of a distinguished geologist "whether in a single case they extend much beyond the light of day."* His remark refers to the upper hundred feet of the Cincinnati group. An excellent opportunity for the study of caves in this Lower Silurian rock is afforded in bluffs about Madison, Indiana, which rise 400 feet from the thin strata characteristic of that formation, to the massive rocks of the Niagara limestone. Each stream, as it plunges down from the table-land above, washes out the lower layers, leaving the upper as an overhanging ledge. In time, the shallow grotto behind the cascade expands into a spacious amphitheater, 200 or 300 feet wide and nearly as many deep. The roof generally falls by its own weight when these dimensions are exceeded; and the result is finally a ravine with steep walls, encumbered below with large fragments of stone. An examination of the region for twenty miles north of Madison led to our discovering, not only sinks, natural wells, rock-houses and water-swept chasms, but also true caverns, whose roof is the solid limestone of the Upper Silurian, while the excavation itself is in the softer rocks of the Lower. Two miles west of Hanover, Indiana, is a stream that flows toward the Wabash from the very banks of the Ohio. It emerges from a tunnel which is easily threaded for half a mile, and continues uncovered for fifty feet; and then

* Geological Survey of Kentucky (Shaler), vol. i, p. 4.

it again recedes by a second opening. We followed its course through roomy halls rich in stalactites to a waterfall fifteen feet high, where the exploration terminated. The entire distance traversed was, by estimate, one mile and a half—a greater length than that of Weyer's Cave. The credit of discovering this *Silurian* cavern belongs to Messrs. Monfort and Thomson; and as it is now for the first time described, it may be appropriately named the Hanover Cave.

2. *Sub-Carboniferous Caves.*—The procedure of the brook described above is reversed in the case of Lost River, which, after receiving tributaries and increasing in volume, flows *into* a cavernous opening and continues for miles along a subterranean channel, alternately rising to the surface and sinking again several times before it finally emerges a mile below Orangeville, Indiana. These "rises" as they are called, are generally marked by gulfs denoting the fall of superincumbent rocks; at one of them a small boat has been put upon the stream, it having been found to be navigable for a long distance under ground. Lost River flows amid bluffs of the Saint Louis group, carved by erosion into numerous ravines and sink-holes, and the latter so thoroughly underdrain the region as to cause a remarkable absence of springs, brooks and ponds.

These phenomena are instructive as to the production of the countless caves that honey-comb the Sub-carboniferous rocks of Kentucky and Southern Indiana. A compact and homogeneous limestone, varying from 25 feet to 440 feet in measured thickness, lies between the surface and the level of natural drainage, subject to the dissolving and eroding action of running water. The result, in time, is a succession of arches, galleries and avenues, presenting wonderful and grotesque combinations to the explorer when the stream that has caused them is withdrawn to some other channel. The slow trickling of limewater furnishes materials for the growth of stalactites that tend to gradually close up and obliterate these deserted halls. Should Lost River find another channel, the cave which would remain might equal in proportions any hitherto discovered. There are no doubt numerous unexplored and nameless caves that would richly reward those whose love of adventure should lead them to follow out their ramifications. Professor Shaler estimates that, in Kentucky, "there are at least 100,000 miles of open cavern beneath the surface of the Carboniferous limestone;" and my own observations lead to the conclusion that there are thousands of miles of such subterranean avenues beneath the same formation in Indiana. Yet the public should be cautious in yielding credence to cave-stories. Articles appeared in Louisville papers less than a year ago, and were copied and believed in this country, and

even found their way into foreign periodicals, that purported to describe the "Grand Crystal Cave near Glasgow, Kentucky" giving thrilling particulars of a perilous voyage on its mysterious waters. We ascertained by inquiry on the spot that no such cave exists; and have learned by experience that cave-streams are generally very safe and placid bodies of water, by reason of the fact that they are not of navigable size until the level of adjacent streams is nearly reached.

3. *Mammoth Cave* is visited by more than 2,000 persons annually, and its noteworthy features have been repeatedly described. Tourists are usually content with either the Short or the Long route, both of which can be traversed in a single day. We, however, were favored with a special guide, and devoted many successive days to localities not often visited. After eighty miles of underground travel, our curiosity was satiated; and yet we had entered only 54 of the 225 avenues reported by Professor D. D. Owen as actually enumerated. The comparatively recent discovery of a pit-like passage called "the Corkscrew," is of importance, not only because it enables the visitors to cut off two miles between the Rotunda and River Hall by an abrupt descent of 150 feet; but also because it proves the theory that the cave crosses its own track, so that a change is required in the entire map. It is now believed that the cascade falling over the mouth and instantly sinking through the rocks is identical with that at the head of the River Styx, and is a feeder of that stream. It is also proved that these deep and navigable rivers, instead of being fed by Green River, flow into it. Chaff thrown upon the surface of Lake Lethe reappears after some time in the waters of what is known as the Upper Big spring; while that thrown upon Echo River comes out at the Lower spring. The fact that Green River is thus replenished explains the peculiarity of its never being frozen over even in the coldest winter. It may be added that as the water-level is known to be 312 feet below the crest of the hill covering the cave, the subterranean rivers must be at a little less than that number of feet beneath the surface, and must also be the lowest localities possible. Hence no dome in Mammoth Cave could exceed 312 feet in height without cutting through to the open air; by which test may be corrected the statements of those imaginative writers whose estimates are nearly double what they should be. The grandest of these vertical cavities, piercing from some sink-hole above through all the galleries down to the water-level, is called, by way of eminence, the Mammoth Dome. Beyond it lies a stately hall, so like the ruins of Karnak and Luxor that we had permission to name it the Egyptian Temple. Here stand six columns of oölitic limestone encrusted with a stalagmitic coating but an inch or two

in thickness and as yellow as jasper. We measured one that arose eighty feet from what we regarded as its base to the ceiling, and found it twenty-six feet in its longest diameter Descending into a pit, we found what we named the Catacombs, opening into an avenue about three miles long.

The acoustic properties of Echo River passage-way are extraordinary. This body of water is said to be rather less than one mile in length and to be forty or fifty feet deep. The continued arch of natural masonry by which it is spanned, varies in height from three to thirty feet. The echo is a musical prolongation of sound, rather than a distinct repetition of words, although this also may be obtained. Harmonics were produced in reponse to certain key-notes. A strong vocal impulse was prolonged with sustained vigor for fifteen seconds, and in the opinion of others for a longer time; the duration depending much on our location on the water, the purity of tone, the pitch and the energy of the original aërial vibrations. By silently but forcibly pushing the water to and fro with a broad paddle, successive wavelets were sent into numerous marginal cavities, awakening chimes that continued for from three to ten minutes according to the violence of the agitation, dying away as the river regained a state of quiescence.

The average temperature of the cave has long been reported incorrectly to be 59° Fahr. Temperature observations were made by us in all parts of the cave that we visited, using a thermometer from the Tower Company, Chester, Pennsylvania, which indicated 88° in the hotel office (August 19th, 1878,) and 66° at the cave's mouth. We were careful to suspend the instrument by its ring in each instance, and to hold it at a distance from the person and the lamp; particulars about which others may not have taken sufficient pains. The mercury stood highest in the Rotunda, where it reached 58°. The lowest temperature was found in Lucy's Dome, namely, 54°. It was 57° in three places: but in forty-two observations the mercury stood at 56°. The water in all the rivers was also at 56°, instead of at 54°, as often stated. In three springs the mercury fell to 53°, and in one, Richardson's Spring, to 52°, which was the lowest degree marked anywhere. The temperature of the rivers is identical with that of the atmosphere over them; the apparent difference being due to variation in conductivity. The average temperature of the cave may be fixed at 56°.

4. *Wyandot Cave.*—The entrance to Wyandot cave is in Crawford County, Indiana, half a mile from Blue River and five miles from the Ohio. A map of the cave was prepared by Dr. Talbot in 1852, revised by me in 1854, and published in Owen's Indiana Geological Report, in 1860. A new map is shortly to appear noting corrections and recent discoveries. The length

of the cave is twenty-three miles, including all the avenues. It has many fine halls and domes, the largest of which has a circumference of 1,000 feet, and is said to be 205 feet high. The name has hitherto been Mammoth Hall; but it is now re-named Rothrock's Cathedral, to avoid confusion, and also as a tardy recognition of the worthy man who originally purchased the place from the government and left it as a heritage to his sons. Wyandot Cave should be visited even by those who have already explored the greater cavern of Kentucky; for it is far richer in stalactitic ornamentation, although less abounding in gypsum rosettes or "oulopholites." The stalactites are of the fine-grained translucent kind often called alabaster, and much resembling the Mexican onyx.

Thermometrical observations, made by the same instrument and methods used in Mammoth Cave, showed that, while the temperature of the outer air was 76°, that of Wyandot Cave averaged 55½°. The highest temperature was found in the Pillared Palace, 57°; the lowest in the Wyandot's Council-room, 54°; elsewhere, out of twenty-two observations, an equal number indicated 55° and 56°. In two springs the water was found to have a temperature of 52°, and in one of 54°. Thus, instead of being, as has often been said, 6° colder than Mammoth Cave, we found it only half a degree colder.

An important discovery was made last April by a party of students from Wabash College, led by Mr. C. E. Milroy. Forcing their way through a low, narrow passage for fifty feet from a locality marked on the map as the Rugged Pass, they entered a realm of chaos, named, after its discoverer, Milroy's Temple. Pits, miry banks, huge rocks, are overhung by galleries of creamy stalactites, vermicular tubes intertwined, frozen cataracts and all in short that nature could do in her wildest and most fantastic mood. Among the many curiosities of this extraordinary place is a row of musical stalactites, very broad and thin, on which a chord can be struck or a melody played by a skillful hand. This discovery has stimulated research. We ourselves followed the guide through a trench dug by him in a clay-bank, into a chamber where the floor was thickly strewn with charred fragments of hickory bark, and two torches long extinct were sticking in a crevice in the low ceiling. The tracks of some wild beast were also found which led us to name the place the Wolf's Lair. The roof seems to have fallen in since the torches were left here; and our compass told us that the closed avenue must have led to Banditti Hall, within 1,200 feet of the mouth. Animals of various kinds are known to have frequented this cave in former days. We saw the skeleton of an opossum and also of a wild cat, besides many stout poles from five to eight feet long, marked by sharp teeth in some ancient contest. "Bear-slides" are shown in several

places, where the rocks are blackened and polished as if by the rubbing of fur. "Bear-wallows," are also pointed out; but on our recent visit we discovered this to be a misnomer.

Bands of black flint are found in the limestones of the south arm of the cave, sometimes in continuous belts, but oftener in rows of nodules varying in size from one to ten inches. Occasionally they have a geodic form and a crystalline center, showing that the siliceous particles had collected about a fossil nucleus. Between these belts, or rows, is usually a chalky substance easily cut with the knife or even by the finger nail. The so-called "bear-wallows" are where the flint is most abundant and of the best quality, as near the Pillared Palace.

Beside each depression is a pile of ashes with bits of hickory bark. Digging into the wallow, quantities of flint chips were brought to light. Piles of flint blocks abound in which were hundreds of them, each piece having parallel faces, and averaging four inches in length, one or two inches in width and one-half inch in thickness. It was evident to me that they were split by the Indians from the oval nodules as materials for arrow tips or spear heads. We found quartz pounders with which the splitting may have been done; but no manufactured articles except a small saucer cut from sandstone which had once held some black substance. The place was plainly a mine and not a factory. Our search at the mouth of the cave was rewarded by the discovery of quantities of flint chips and also a number of finished arrow heads.

Indian foot-prints were visible in all parts of the new cave when first explored; and I saw them in 1854, although now they are obliterated. The cane torches, so abundant at "Chief City" in Mammoth Cave, which were supposed to be filled with bear's fat when ready for use, are rarely found in Wyandot Cave, which seems to have been lighted by bundles of hickory bark ignited by splinters of various kinds of wood.

What is known as the "Old Cave" was worked by saltpeter miners in 1812, and sundry acts of vandalism have been charged on them, which it is more probable were done by the aborigines. The finest stalacto-stalagmitic column probably in the world is the Pillar of the Constitution at the end of the Old Cave, three miles from the mouth. It is 40 feet high, and 25 feet in diameter, and it rests on a base 300 feet in circumference. The weight of this immense mass of alabaster caused the subjacent rocks to settle, and this in turn cracked the base, opening crevices many yards long, and varying in width from two inches to one foot. A large segment has been cut from the base of this column. Starting from the crevices, an excavation was made cutting a mass from the base having an arc of thirty feet, and making a cavity into the pillar itself ten feet wide, seven feet high and five feet deep. This excavation has hitherto been

regarded as a deliberate plan of the miners to fell the column. But we have a different explanation to offer. Tracing the right edge of the cut we find it running underneath a stalagmitic wrapping, eight feet wide and ten inches thick at its thickest part. Inspection shows that drippings like those now healing this wound were at work before it was inflicted, and that the incision was made through a mass similar to that by which it is at present overlapped. Rothrock's experiments, carefully carried on for a long term of years, fix the rate of stalagmitic growth in this portion of the cave at one inch a century.* Hence the excavation, instead of being made in 1812 must have been completed a thousand years ago. Its age may exceed that, and it cannot be much less. Following the talus of pure white stones that have rolled down under the ledges of black limestone, we find them sometimes cemented over a cavity where nature has had time to produce groups of exquisite stalactites since the quarry was worked, confirming the explanation above given. Further search enabled us to discover the tools with which the ancient workmen wrought, whoever they were, namely, numerous round or oblong granite bowlders, extremely hard, and of a size suitable to be grasped by the hand or twisted in a withe and swung as a maul. They could not have been carried to the end of the cave by the action of water, for it is twenty feet higher than the mouth. The region, moreover, is south of the line of Glacial drift. It seems certain, hence, that they were brought from a distance by persons having access to no better tools. Their ends also are battered and whitened by use as pounders. No manufactured articles were found on the spot; and only shapeless disintegrated fragments were upturned at the mouth of the cave. It is our conclusion that from this alabaster mine, blocks of a convenient size were carried away, perhaps by successive generations, as a choice material for ornaments and images. Those who wrought here by torchlight may have been of the same race that dotted the Ohio valley with mounds, and whose era, according to Mr. C. C. Jones (Mon. Remains of Georgia, p. 59) was synchronous with the date of the mine as estimated in this article. Ornaments of alabaster have been repeatedly exhumed among Indian relics in the Southern States; and more careful research may find similar objects amid the tumuli of Indiana, though perhaps not abundantly. For alabaster, though a very durable material, when not exposed to the elements, is fibrous in its nature, and would be liable to decay amid the frosts and sunshine of ten centuries; as we know from the crumbling specimens found outside in the vicinity of the cave.

* Dr. Binkerd's estimate of stalagmitic growth in Mammoth Cave fixed it at one inch in 7,500 years; which makes Rothrock's estimate seem very moderate indeed! (See Binkerd's Mammoth Cave, p. 54.)

Art. LVI.—*The Chinese Official Almanac;* by Professor Mark Harrington.

This document, highly important to about one-third of the human race, is issued annually in December and is carefully prepared by the Board of Astronomy, an important body, imperially appointed, presided over by a prince of the royal blood, and equal in dignity to any other government body in the empire. The Almanac is bestowed as a special act of grace by the emperor on the Coreans, Lewchewans, Annamites and other tributary states. As this publication is so highly respected by the Chinese it may fairly be considered as the representative of the highest state of astronomical science reached by them, and it is therefore worth our while to examine it carefully.

On examining one of these books we find it to consist of two distinct parts, the astronomical and the astrological, the latter being much more fully represented than the former. Taking up first the astronomical part, we find that eclipses of the sun and moon are not mentioned. These are not printed in the Almanac, but, as the writer was informed by an employee of the Astronomical Board, are computed and published just before their occurrence. It is well-known to foreigners resident in China that the predictions are never accurate, but are sometimes as much as an hour in error.

The times of sunrise and sunset are given for forty-eight days in the Chinese year. The dates are from three days to fifteen apart, and the intervals are smallest when the sun is changing his declination most rapidly. The times of rising and setting are very symmetrically arranged and the same hours are repeated from year to year. As it is the hour of rising and setting that is repeated, and as the Chinese month is the lunar one, the dates are changed each year. Were it not for typographical errors the arrangement would appear very accurate and neat. By examining the Almanacs for several years we are able to eliminate the blunders in the plates, and we then make out that the figures are the semidiurnal arcs of a star having a declination equal to that of the sun on the given date. This is easily seen from the accompanying table (A). The third year of Kuang Hsü began with the new moon in February, 1877, and each successive month with the successive new moons. The fourth year of Kuang Hsü began with the new moon of February, 1878, and the twelve months follow as in the preceding year.

It will be observed that in the rising and setting of the sun as given in this table the corrections are altogether absent.

A.—*Times of Sunrise and Sunset at Peking, as given in the Chinese Almanac, with the corresponding semi-diurnal arcs.*

YEARS 3D AND 4TH OF KUANG HSÜ, 1877–79.

Chinese Month and Day.		Chinese Time of		Corresponding Semi-diurnal Arc.
3d Year.	4th Year.	Sunrise.	Sunset.	
V 11	V 21	4·35	7·25	7·25
IV 24	V 6			
V 27	VI 8	4·38	7·22	7·21
IV 12	IV 23			
VI 10	VI 21	4·46	7·14	7·14
IV 3	IV 13			
VI 19	VI 30	4·54	7·06	7·07
III 25	IV 7			
VI 25	VII 6	5·00	7·00	7·00
III 19	IV 1			
VII 2	VII 13	5·06	6·54	6·54
III 13	III 24			
VII 9	VII 19	5·13	6·47	6·47
III 7	III 18			
VII 15	VII 25	5·21	6·39	6·40
III 1	III 28			
VII 21	VIII 2	5·28	6·32	6·33
II 25	III 6			
VII 27	VIII 9	5·36	6·24	6·25
II 18	II 30			
VIII 5	VIII 12	5·44	6·16	6·16
II 12	II 24			
VIII 11	VIII 21	5·52	6·08	6 08
II 6	II 18			
VIII 17	VIII 27	6·00	6·00	6·00
I 30	II 12			
VIII 23	IX 4	6·08	5·52	
I 24	II 6			
VIII 29	IX 10	6·16	5·44	
I 18	I 30			
IX 5	IX 16	6·24	5·36	
I 12	I 24			
IX 11	IX 22	6·32	5·28	
I 6	I 18			
IX 17	IX 28	6·39	5·21	
	I 12			
IX 23	X 4	6·47	5·13	
	I 6			
IX 29	X 10	6·54	5·06	
XII 30				
X 6	X 16	7·00	5·00	
XII 24				
X 12	X 22	7·06	4·54	
XII 15	XII 14			
X 21	XI 2	7·14	4·46	
XII 3	XII 14			
XI 3	XI 14	7·22	4·38	
XI 18	XI 29	7·25	4·35	

The equation of time is disregarded as is common to most oriental nations. This custom takes its origin in the use of sun-dials and is natural when the use of time-keepers is not common. We are not quite justified therefore in looking on the absence of this correction as a fault in the Chinese Almanac. But the corrections for semi-diameter and for refraction are also absent and for their absence we can find no excuse. These corrections at Peking may amount to more than five minutes. The times given in the Almanac are correct only when the corrections neutralize each other, and as that is only twice each year for sunrise or sunset we find that only about four per cent of these predictions are correct in the Almanac.

B.—*Times of Moon's Quartering at Peking, as given in the Chinese Almanac.*

3D YEAR OF KUANG HSÜ, 1877–78.

Foreign date.	Chinese date.	Foreign time.	Chinese time.	Diff.	Foreign date.	Chinese date.	Foreign time.	Chinese time.	Diff.
	I.					VII.			
Feb. 13	1	4·45 P.M.	4·38 P.M.	− 7	Aug. 9	1	1·03 P.M.	1·09 P.M.	+ 6
21	9	12·01 P.M.	11·51 A.M.	−10	16	8	6·14 P.M.	6·13 A.M.	− 1
28	16	3·00 A.M.	2·56 A.M.	− 4	24	16	6·57 A.M.	6·54 A.M.	− 3
Mar. 7	23	5·47 A.M.	2·58 A.M.	+11	Sept. 1	24	5·01 A.M.	5·09 A.M.	+ 8
	II.					VIII.			
15	1	10·40 A.M.	10·40 A.M.	0	7	1	8·46 P.M.	9·00 P.M.	+14
22	8	8·55 P.M.	9·01 P.M.	+ 6	14	8	6·45 P.M.	7·01 P.M.	+16
29	15	1·35 P.M.	1·39 P.M.	+ 4	22	16	11·21 P.M.	11·29 P.M.	+ 8
April 6	23	12·16 A.M.	12·18 A.M.	+ 2	30	24	2·06 P.M.	2·22 P.M.	+16
	III.					IX.			
14	1	1·36 A.M.	1·47 A.M.	+11	Oct. 7	1	5·44 A.M.	6·07 A.M.	+23
21	8	3·23 A.M.	3·38 A.M.	+15	14	8	11·28 A.M.	11·47 A.M.	+19
28	15	12 22 A.M.	12·31 A.M.	+ 9	22	16	3·17 P.M.	3·34 P.M.	+17
May 5	22	7·05 P.M.	7·13 P.M.	+ 8	29	23	10·07 P.M.	10·31 P.M.	+24
	IV.					X.			
13	1	1·15 P.M.	1·26 P.M.	+11	Nov. 5	1	4·34 P.M.	4·59 P.M.	+25
20	8	8·42 A.M.	8·59 A.M.	+17	13	9	7·30 A.M.	7·51 A.M.	+21
27	15	11·51 A.M.	12·04 P.M.	+13	21	17	6·05 A.M.	6·28 A.M.	+23
June 4	23	12·57 A.M.	1·03 P.M.	+ 6	28	24	5·51 A.M.	6·13 A.M.	+22
	V.					XI.			
11	1	10·18 P.M.	10·29 P.M.	+11	Dec. 5	1	5·50 A.M.	6·06 A.M.	+16
18	8	2·10 P.M.	2·20 P.M.	+10	13	9	5·20 A.M.	5·30 A.M.	+10
26	16	12·39 A.M.	12·41 A.M.	+ 2	20	16	7·37 P.M.	7·50 P.M.	+13
July 4	24	4·48 A.M.	4·51 A.M.	+ 3	27	23	2·06 P.M.	2·18 P.M.	+12
	VI.					XII.			
11	1	5·52 A.M.	5·56 A.M.	+ 4	Jan. 3	1	9·49 P.M.	9·51 P.M.	+ 2
17	7	8·58 P.M.	8·57 P.M.	− 1	12	10	2·33 A.M.	2·30 A.M.	− 3
25	15	3·05 P.M.	3·02 P.M.	− 3	19	17	7·57 A.M.	7·55 A.M.	− 2
Aug. 2	23	6·07 P.M.	6·09 P.M.	+ 2	25	23	11·35 P.M.	11·35 P.M.	0

The times of the moon's quarters and of the twenty-four Chinese seasons are also given, and as they are given to the

minute, it is a fair presumption that they are offered as correct. But an Astronomical Board which can not compute the time of sunrise can hardly be expected to be accurate in its calculations on the moon's motions. Table B shows the amount of the error for the last year. The errors are not eliminated when we use apparent time in the foreign times. By examination of the Chinese predictions for two years we find the range of error is from fifteen minutes fast to twenty-six minutes slow, or a total range of forty-one minutes, while the percentage of correct predictions is only three. The character of the errors involved defies solution.

The Chinese year is divided into twenty-four seasons, about fifteen days apart and depending on the sun's right ascension. The most of these, such as "little cold," "great cold," "rain-water," "excited insects," etc., are not recognized by western science, but four of them, viz., the equinoxes and solstices are common to astronomy universal, and can fairly be criticised by foreigners. According to the Chinese the sun is at the vernal equinox at 7 h. 43 m. P. M. According to foreign calculation the Peking time for the same phenomenon is 7 h. 26 m. P. M.,—making the Chinese 17 m. slow. Their summer solstice is 29 m. slow; autumn equinox 49 m. slow; winter solstice 35 m. slow.

The preceding quotations are for Peking; the accompanying foreign times are computed from the British Nautical Almanac and reduced to Peking local time. The position taken for Peking was, longitude 116° 26′ east, latitude 39° 55′ north. The Imperial Almanac also gives predictions for several other points scattered over the empire, but the predictions are more complete and probably quite as accurate for Peking as for the other points.

We come now to the part of the Almanac which the Chinese consult much oftener and consider much more important, viz. the astrological portion. Much of this is made intentionally obscure; for the full comprehension of it a prolonged study of Chinese philosophy and astrology would be necessary,—and a more barren field for scientific research could hardly be conceived. The remainder which makes up the body of the Almanac is intended to be a practical guide in the common affairs of life. The following is a translation of this part for the first few days of the current Chinese year.

The first day is favorable for sacrifice and for entering school; at noon it is allowable to bathe. It is unfavorable for starting on a journey or changing residence.

The second day is favorable for sacrifice and bathing. It is unfavorable for starting on a journey, removing or practising acupuncture.

The third day; there are no indications.

The fourth day; may receive or make visits and cut out clothes; at 7 A. M. may draw up contracts, barter and make presents. May not go on a journey nor break ground.

The fifth day; may visit, bathe, shave and clean up. May not plant and sow.

The sixth day is favorable for sacrifice, conjugal union, visiting, taking on a new servant, starting on a journey, removing, marrying, repairing, building, breaking ground; at 3 A. M. may draw up contracts, open shop, barter, send presents, seal, test the soil and bury.

The seventh day; may level roads but must not start on a journey.

The eighth; may sacrifice, memorialize, enter office, assume ceremonial clothes; at 5 A. M. may sit toward the southeast; also favorable for conjugal union, visits, weddings, taking on a new servant, starting on a journey, erecting uprights and putting on crossbeams, building, removing soil and burying.

And so it goes on for nearly every day in the year. Enough has been translated to show the excessive childishness and absurdity of this, the principal part of the Imperial Almanac. On the 17th one may be treated for illness and open *caches* of provisions. On the 22d it is allowable to pull down old houses and walls but drains must not be opened or wells dug until the 27th. Arrests should be made on the 25th; this is the only favorable day in the month—a very satisfactory arrangement for criminals. There are four days in 30 on which one may cut out clothes and the same number on which one may sweep and clean up. It is advised to shave on the 5th, 23rd, and 29th, and to bathe 7 times in the month. Unfortunately the intervals between the bath-days are unequal, and the believer in the Almanac must wait from the 5th to the 13th and from the 14th to the 23d. Besides on the 1st bathing is favorable at an inconvenient hour, viz. noon; the hour on the 29th (5 o'clock) is much better.

These indications seem too silly to affect sensible men, yet while the Chinaman is not only sensible but actually shrewd and keen, he guides the most of his more important affairs by the Almanac. The poorer classes watch the Almanac carefully and marry, bury and do other things only when it advises, and it is to be feared that the better educated do not start on a journey nor enter office except on favorable days, though it is to be hoped they bathe, shave and clean oftener.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of Carbonic Acid in Mineral waters.*—Borchers has proposed a new method for determining both the free and the combined carbonic acid of a mineral water. He uses in general the apparatus devised for this purpose by Classen, but modified in its details to suit the new method. It consists of a flask to contain the water to be tested, through the cork of which two tubes pass; one a safety tube, ending near the bottom, through which hydrochloric acid can be poured and air aspirated; the other attached to an upright condenser surrounded by a cooling cylinder. From the top of this condenser passes a rubber tube to a U-tube filled with glass beads moistened with sulphuric acid. To this is joined a Liebig's potash bulb, a soda-lime tube and an aspirating bottle. With this apparatus three preliminary experiments were made. In the first, hydrochloric acid of sp. gr. 1·06, was boiled in the flask for an hour, and then air free from CO_2 aspirated through it; the potash apparatus lost 0·0120 gram and the soda-tube gained 0·0115 gram; thus proving the perfection of the apparatus. In the second, a measured volume of cold water saturated with carbonic acid, was placed in the flask and gradually heated to boiling, air being drawn through afterward. The increase of weight of the potash bulb and soda-lime tube, representing the carbonic acid, agreed well with the amount obtained by Fresenius' method; thus proving that the free carbonic acid of a water is entirely driven out by this method of treatment. In the third experiment, it was proved that by sufficient boiling, the carbonic acid combined as acid carbonate (bicarbonate) could be wholly driven off. The analysis is made as follows: The mineral water, previously well cooled, is introduced into the flask by fitting to the bottle containing it, a cork carrying two tubes like those of the ordinary wash-bottle. The flask preferred is of the form known as Erlenmeyer's, a mark being made upon the side to measure the quantity introduced. After connecting it with the apparatus the liquid is heated gradually to boiling, this boiling being continued till the solution in the potash bulb begins to retreat. A liter of air is then drawn through the water, the boiling and the following aspiration being repeated one or more times according to the amount of bicarbonate present. The increased weight of the potash bulbs and the soda-lime tube is then noted, as the free carbonic acid. By means of the funnel tube, hydrochloric acid is allowed to enter the flask slowly to decompose the carbonates. The liquid is then boiled and aspirated as before. The second increase of weight represents the combined carbonic acid. Treating the Selters water in this way, a liter of water gave free carbonic acid 2·4911 grams, combined 0·5699, total 3·0610 grams, against 3·0934 found by Fresenius. Ems

Kränchen gave free CO_2 1·5277, combined 0·6782, total 2·2059 grams. Carlsbad Schlossbrunnen 1·4122 free CO_2, 0·7966 combined CO_2, total 2·2088 grams. Marienbad Kreuzbrunnen 2·6355, combined 0·9055, total 3·5408 grams.—*J. pr. Ch.*, II, xvii, 353, July, 1878. G. F. B.

2. *On Ultramarines of various metals.*—The production from the blue ultramarine containing sodium, of a yellow ultramarine in which the sodium is replaced by silver, was accomplished some time ago by Heumann by heating the former substance, mixed with a concentrated solution of silver nitrate, to 120° in a sealed tube. The attempt to form other analogous ultramarines in this way was a failure. DeForcrand and Ballin have now succeeded in devising a general method of preparing ultramarines containing different metals, and by which they have already produced potassium, barium, zinc and magnesium ultramarines. The process consists in producing the yellow silver ultramarine by the above method and then in heating an intimate mixture of this with the metallic chloride desired. To produce the silver product, the authors heated, for fifteen hours, ten sealed tubes, each containing five grams of blue ultramarine and ten grams of silver nitrate in concentrated solution. On opening the tubes, seventy-five grams of pure silver ultramarine was obtained containing 46·63 per cent. of silver. Under the microscope it appeared a perfectly homogeneous mass of transparent yellow grains. It contained silicon, aluminum, sulphur, silver and oxygen; is insoluble in water, and undecomposable by strong acids. Heated with an intimate admixture of sodium chloride repeatedly, the sodium replaces again the silver and a blue ultramarine is obtained, of a more beautiful shade, and containing less of violet than the original ultramarine; a difference due to the slight loss of sulphur. If potassium chloride be used, a bluish-green ultramarine is produced. Barium chloride gives a yellowish-brown, zinc chloride a violet, and magnesium chloride a gray compound, having all the properties of ultramarine.—*Bull. Soc. Ch.*, II, xxx, 112, August, 1878. G. F. B.

3. *On Chrome Steel.*—Boussingault has made an investigation into the production, the constitution and the properties of the so-called chrome steel. This steel is prepared by mixing in the crucible the required proportions of any suitable steel and an alloy of iron and chromium called ferro-chromium. This alloy is obtained by the direct reduction of chromic iron, and when made in the crucible may contain sixty to seventy per cent of chromium, but only seven to ten when made in a high furnace. The discovery of this steel, the author attributes to Berthier in 1820, and gives extracts from his memoir describing his experiments. He made two chrome steels, one containing 0·010, the other 0·015 of chromium, which were of excellent quality and were worked into cutlery. Boussingault made two experiments to test the question whether chromium alone could give to iron the property of tempering. One of these steels contained 0 010 of chromium and 0·001

of carbon, the other 0·0124 of chromium and 0·0031 of carbon. The first could not be tempered at all, and the other only to the extent of the carbon in it. Further experiments with iridium and osmium showed that these metals could not give to steel the property of hardening. He points out the fact that in 1867 in Antioquia in Central America, a cast iron was made containing from two to four per cent of chromium, and concludes with a description of the process of making ferro-chromium and chrome steel in the works at Unieux.—*Ann. Chim. Phys.*, V, xv, 91, Sept., 1878.

G. F. B.

4. *On the Etherification of the Primary Alcohols.*—MENSCHUTKIN has studied the influence of the isomerism of the alcohols and acids upon the formation of their compound ethers, and in the present paper gives a table showing the percentage of acetic acid etherified by the different primary alcohols at 154°. As to the velocity of this etherification, the first place is taken by methyl alcohol; then follow the primary saturated and then the primary unsaturated alcohols. The author calls the velocity of the reaction during the first hour, expressed in percentages of the ether formed, the starting-velocity. By absolute velocity he distinguishes the ratio between the quantity of the acid or alcohol etherified and the whole quantity taken; by relative velocity the ratio of the portion etherified during the first hour to the whole quantity finally etherified. The absolute starting-velocity of methyl alcohol is 55·59, the relative 80·8. The saturated normal primary alcohols have the same absolute starting velocities, though after the first hour, alcohols with high molecular weight show greater absolute velocities than those of smaller molecular weight. The relative starting velocity lessens with increasing molecular weight in the case of the normal primary alcohols. The influence of isomerism, though distinct in the case of absolute, is more marked in the case of relative starting velocity. The velocity of etherification is less in the unsaturated primary alcohols. To estimate the limit of the etherification, numbers are taken representing the final percentage etherified, beginning with 120 hours. With the exception of methyl alcohol, the percentage increases with the molecular weight. Isomerism affects the velocity of etherification, not its limit. The unsaturated primary alcohols show lower limits than saturated alcohols having the same number of carbon atoms.—*Ber. Berl. Chem. Ges.*, xi, 1507, Sept., 1878.

G. F. B.

5. *On the Preparation of Allyl Bromide.*—The present mode of preparing allyl bromide, by dropping phosphorous bromide on dry allyl alcohol, is tedious and possibly dangerous. GROSHEINTZ has shown that this ether may be readily prepared by distilling a mixture of allyl alcohol, potassium bromide and sulphuric acid. The best way is to add to the potassium bromide the sulphuric acid diluted with its volume of water, and to heat the mixture in a distilling apparatus. When the hydrobromic acid begins to be evolved, the allyl alcohol is allowed to fall drop by drop into the liquid. The allyl bromide, which distils over with the vapor of

water, is washed with water slightly alkaline and dried over calcium chloride.—*Bull. Soc. Ch.*, II, xxx, 98, August, 1878.

G. F. B.

6. *On a New Method of preparing Aldehydines.*—LADENBURG showed some time ago that the orthodiamines could be readily distinguished from the meta and paradiamines by the fact that the former produce with aldehyde permanent bases which he called aldehydines. He has now proposed a new and simple method of preparing these aldehydines, which consists simply in agitating a dilute aqueous solution of the orthodiamine hydrochlorate with aldehyde. A tenacious mass is at first formed, which after a long time on standing, or more quickly on adding alcohol, passes into a colorless crystalline hydrochlorate of the new base. Recrystallization gives it pure. The yield is from fifty to seventy per cent.—*Ber. Berl. Chem. Ges.*, xi, 1648, Sept., 1878.

G. F. B.

7. *On the Constituents of Corallin.*—ZULKOWSKY has reëxamined the substance known as corallin and has succeeded in obtaining from it two homologous bodies corresponding to the two homologous rosanilines discovered by Emil and Otto Fischer, the rosanilines being the triamido and the rosolic acids the trioxy-derivatives of a hydrocarbon constituted like diphenylphenylenemethane. The first of these rosolic acids crystallizes in needle masses, dark rose-red by transmitted light, with a magnificent metallic-green reflection. It has the formula $C_{20}H_{16}O_3$. The second is garnet-red, crystallizes in right rhombic prisms, has a blue metallic reflection and affords on analysis the formula $C_{19}H_{14}O_3$. —*Liebig's Annalen*, cxciv, 109, Sept., 1878.

G. F. B.

8. *On a New Organic Base in the Animal Organism.*—SCHREINER has examined a crystalline substance found under various conditions in the animal organism. It was prepared from the spermatic fluid by boiling with alcohol, filtering, drying the residue at 100°, and extracting with warm water containing a few drops of ammonia. On evaporation monoclinic crystals are obtained, which proved to be the phosphate of a new base, whose hydrochlorate had the formula C_5H_5NHCl.—*Liebig's Annalen*, cxciv, 68, Sept., 1878.

G. F. B.

9. *Persulphuric Oxide* S_2O_7.—Since his earlier paper on the subject, noticed in our March number, BERTHELOT has published the results of a more extended investigation of this new compound. The most interesting points established are those connected with its thermal relations. In the fixation of oxygen gas to form persulphuric oxide, heat is absorbed, and hence in its decomposition heat is evolved, and the loss of energy in the successive stages from ozone to oxygenated water, from oxygenated water to persulphuric oxide, and from persulphuric oxide to ordinary oxygen are beautifully traced, the total change being represented by 14·8 units of heat.

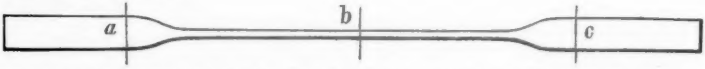
Thus M. Berthelot has furnished us with another illustration of the general principle which his investigations have served so

greatly to illustrate. Persulphuric oxide is an example of a remarkable class of compounds whose formation is attended with the absorption of heat, and whose production can only be determined by the expenditure of some mode of energy. Corresponding to these circumstances of their genesis are the facts that these compounds are very unstable, and that when they decompose into more stable products the heat previously rendered latent becomes free. Now in accordance with the mechanical theory of heat we are forced to the assumption that the expenditure of energy attending the production of such unstable compounds gives to the parts of their molecules a certain energy of position, which energy becomes free when these parts fall back into a more stable equilibrium. But this evidently implies that the molecules have a certain structure, and if so, this structure is a legitimate subject of investigation. We find it therefore difficult to understand why it is that M. Berthelot, while furnishing chemistry with some of the most important facts on which the modern theories of molecular structure are based, should so persistently disparage the results of those who are investigating the same subject from a different point of view, and whose conclusions are, at least, as trustworthy as his own. In the present series of papers, Ann. de Chem. et Phys., July, 1878, Dumas' theory of types is revived and advocated as more philosophical than the generally received doctrine of atomicities, on the ground that it is not so much the nature of the radicals as the so-called *type of combination* which determines the qualities and chemical relations of the resulting products. But in the present state of science what conception can we form of a *type of combination* except as a mode of atomic grouping? and what is the doctrine of atomicities except an attempt at a representation of the habitual mode of grouping of the various atoms, and assuredly the great class of chemical students whose doctrines Berthelot condemns, are all engaged on the one problem of tracing the physical as well as the chemical relations of substances to what they call molecular structure? Lastly, we fail to see what advantage the phrase "type of combination" has over the term "molecular structure." The two expressions suggest the same general thought; but the idea of molecular structure developed as it has been by the investigations of the last ten years, is a more definite conception and one which correlates a vastly larger number of facts than the earlier conception of chemical types, and it must be admitted that the value of a working theory depends solely on its power of correlating facts.

J. P. C., JR.

10. *Acoustic Repulsion.*—In a recent number of the Philosophical Magazine (October, 1878) Lord Rayleigh has given a mathematical explanation of the curious phenomenon of the repulsion of resonators observed by Dvorák and Mayer (Phil. Mag., September, 1878, p. 225.) The conclusion is reached that the resonator tends to move as if impelled by a force acting normally over the area of its aperture and directed *inward.*

11. *Note by* W. GOOLD LEVISON, *on the Sand Filter described in American Journal of Science, September*, 1870, *page* 241.* (Communicated.)—A glass rod of a little larger diameter than the aperture in the neck of the funnel is drawn out to a slender thread as shown below.



This is then cut off by the file at the points *a*, *b* and *c*, forming two pieces. The large end of such a piece being held in the flame soon assumes a globular shape, forming a pear of glass. When this is dropped in the funnel the long stem rests against its side. If the funnel be of very thin glass, so as to weigh but little, and the end of the stem be fused fast to its rim, no jar will loosen the sand or precipitate, and it forms, probably, the most convenient filter for drying precipitates at a temperature that would char paper.

II. GEOLOGY AND MINERALOGY.

1. *Note upon the history and value of the term "Hudson River Group," in American Geological Nomenclature;* by JAMES HALL. (Proc. Amer. Assoc., Nashville meeting, August, 1877.)—The term Hudson River Group was employed in the Reports of the New York Geological Survey for the shales and slates overlying the Trenton limestone. Later it was urged by Sir William Logan, and partially admitted by Mr. Hall, that the slates of the Hudson River region were not of the group, but of the Quebec group, and the name Cincinnati group was suggested by Meek and some other geologists as a substitute. Professor Hall here reviews the facts, and states that subsequently he, with Sir William Logan, after an examination of the region, found that the first conclusion was essentially right; that the "Hudson River group continues uninterruptedly from Saratoga County to Kingston in Ulster County, and, on the east side of the river, is clearly defined along the valley, with a width of one to several miles, through the counties of Washington, Rensselaer, and Columbia, its eastern limit approaching the river near Rhinebeck; and he rightly says, that there is no good reason for abandoning the old name "Hudson River Group."

2. *Paleontological Report of the Princeton Scientific Expedition of* 1877; by HENRY F. OSBORN, WM. B. SCOTT and FRANCIS SPEIR, JR. 146 pp. 8vo, with 10 plates, 1878.—The expedition from Princeton College last summer to Colorado and Wyoming returned with large and valuable collections of fossils as this Report abundantly shows. The Colorado collections were made in the beds near Florissant, supposed to be Miocene, and in those near the Garden of the Gods "referred to the Dakota and

* In the title of the article, here referred to, Mr. Goold Levison's name is wrongly spelt in two of its letters.

Wealden groups," and those of Wyoming, in the vicinity of Fort Bridger, near Smith's Fork, Henry's Fork and Dry Creek. The species embrace Mammals, Reptiles and Fishes. One of the plates represents a magnificent specimen of the skull of a new species of *Uintatherium*, named *U. Leidianum;* and a second species of the genus is named *U. princeps.* A paper on the geological work of the expedition will appear in another number of this Journal.

3. *The Ancient Life-History of the Earth; a comprehensive outline of the principles and leading facts of Paleontological Science;* by Professor H. ALLEYNE NICHOLSON, M.D., etc. 407 pp. 8vo. New York, 1878. (D. Appleton & Co.)—A very convenient text-book for the geological student.

4. *Manual of Mineralogy and Lithology;* containing the elements of the science of minerals and rocks, for the use of the practical mineralogist and geologist, and for instruction in schools and colleges; by JAMES D. DANA. Third edition rearranged and rewritten. 474 pp. 12mo, with many wood cuts. New York. 1878. (John Wiley & Sons.)—The second edition of this manual appeared more than twenty years since. The new edition now published is a new work in nearly all respects, and yet retains the popular feature of the former in its elementary character, and its arrangement of the ores under the head of the prominent metal they contain. In addition, the chapter on rocks has been expanded into a general but brief treatise on the subject containing descriptions of the kinds and their prominent varieties.*

III. BOTANY AND ZOOLOGY.

1. *Shortia galacifolia re-discovered.*—A hundred years ago the elder Michaux collected, somewhere in the mountains of North Carolina, a specimen of a Pyrolaceous-looking plant, out of flower, or rather with corolla and stamens fallen, a dehiscent capsule enclosed in a persistent imbricated calyx and surmounted by a persistent style. It was not noticed in the *Flora Boreali-Americana*, which was prepared by L. C. Richard from Michaux's collections. Early in the year 1839, I found and examined this specimen in Michaux's herbarium, and I received from the hand of M. Decaisne a drawing and some fragments of it. In a paper treating of the botany of these mountains, contributed to this Journal in January, 1842, I ventured to found a genus upon this plant, under the above name, trusting that the diligent search prosecuted by myself and by all botanists visiting the region would duly bring it to light. The protracted failure of these endeavors has thrown an air of doubt over the minds of my associates in the search, as to the actual existence of any such plant. In 1868, I had the pleasure of announcing in this Journal (Ser. II, xi, 402) the discovery of this genus, not indeed where we were

* That students may not be led astray, it is proper here to say that copies of the old edition have been printed by the former publisher of the work, Mr. H. H. Peck, bearing a recent date on the title page, although unrevised since 1857.

looking for it, but where experience had led me to expect that any or every peculiar Atlantic States type might recur, namely in Japan. That is, I identified the genus with the *Schizocodon uniflorus* of Maximowicz, which, singularly enough, was known only by specimens in the same condition, i. e. with calyx and gynœcium, but neither corolla nor stamens. The patent relationship of these specimens to *Schizocodon soldanelloides* of Zuccarini gave ground for a conjectural restoration of the missing organs; and I ventured the opinion that *Shortia* (of 1842) and *Schizocodon* (1843), whether of one genus or two, were most related to *Diapensia*. In the year 1870 (in Proc. Am. Acad., viii, 243) I reconstructed the order *Diapensiaceæ*, referred to a separate tribe, *Galacineæ*, the genera *Galax* and *Shortia*, and adopted the idea of a probable identity of *Schizocodon* with the latter. The next year Maximowicz decided that the two genera should be distinct, founding this conclusion upon the close seed-coat (confirmed in the Japanese *Shortia uniflora*) and the campanulate corolla, with lobes undulate-crenate instead of fimbriate, and upon some characters in the stamens, all these taken from a rude figure in the Japanese *Soo Bokf.*, iv, fol. 8, which is supposed to represent *S. uniflora*, although the leaves would (as Maximowicz rightly observes) refer it rather to *S. galicifolia*, these being all represented as acute or in one dubious case subcordate at base, instead of reniform-cordate. The identification as to genus is doubtless correct; but the analysis of the flower is too rude for reliance as to all relating to the stamens and the squamulæ. Happily I can now give the characters from an actual blossom.

For I have now received, at first indirectly from Mr. J. W. Congdon, and at length directly from Mr. M. E. Hyams, of Statesville, North Carolina, a flowering specimen of the long-sought *Shortia galacifolia*. Mr. Hyams, or more strictly his son, George McQueen Hyams, collected it on a hill-side in McDowell County, North Carolina, in the district I had indicated as the most probable locality, viz: east of the Black Mountain. It was collected in May, 1877, but, as its remarkable interest was unknown, it has only now been communicated to me. I will only state here, that the distinction between the two genera is probably definite, that our plant is perhaps identical in species with the one figured in the Japanese books (rather than with *S. uniflora*), although the corolla in ours is seemingly white, and the crenulation of the border of the lobes is stronger than in the description and often double; that the anther, though not agreeing with Maximowicz's character, probably may agree with this Japanese representative, and may be generically distinguished from that of *Schizocodon*, unless other species afford transitions; and that the squamulæ are like those of *Schizocodon* and fully as large, but broader, narrowed or almost unguiculate at base, and attached to the very base of the corolla, while the filaments (said by Maximowicz to be "libera," probably in the sense of free from the corolla, as they are represented in the Japanese figure) are adnate to the corolla for most of their length. That is, the phrase "filamentis

tubo corollæ adnatis," in Benth. and Hook. Gen. Pl. is correct, but I know no then extant authority for it, except the analogy with its relatives. Less fortunate are the characters: "Antheræ erectæ, didymæ . . . loculis oblique dehiscentibus," derived by Maximowicz from the Japanese figures, and the "antheræ breves . . . loculis divergentibus" of the Genera Plantarum; the anthers being longer than in any other genus of the order, and the cells in a just sense longitudinally dehiscent. But the anther is,—as in all its relatives except the anomalous Galax,—inflexed or incumbent on the apex of the filament, in this genus about horizontal, as are consequently the marginal sutures which run the whole length of the elongated-oblong cells. The pollen is simple and obscurely trigonous as seen on the field of the microscope. The style and stigma are as in *Schizocodon*, but the latter more capitate. A. G.

2. *On the Amount of Sugar contained in the Nectar of various Flowers;* by A. S. Wilson. A paper read before the Dublin meeting of the British Association, August, 1878.—The interest of this paper lies in the determination of the very small amount of saccharine matter secreted by the nectaries of certain flowers commonly visited by honey bees, and therefore the extraordinary industry of insects in their work of collection; or in other words the vast number of blossoms they must visit (and aid to fertilize) in order to lay up the quantity of honey they do. Mr. Wilson estimates from his data that, to obtain one kilo of sugar from red clover, 7,500,000 flowers must be sucked. There are about sixty flowers in a head; and 2,500,000 visits must be made to collect a pound of honey. (Abstr. from Jour. Botany, London, Oct., 1878.)

A. G.

3. *Absorption compared with transpiration.*—In closing a recent article in Ann. d. Sci. Nat., ser. 6, vi, Vesque presents the following abstract of his views.

(1.) Of all the theories advanced to explain the movement of water in plants, that of Boehm is most nearly in harmony with observed facts. [According to Boehm, "the water-movement caused by transpiration is a function of the elasticity of cell-walls, and of atmospheric pressure.]

(2.) Although transpiration is the most potent cause of absorption, these two functions are not necessarily proportional.

(3.) Absorption is equal to transpiration when the plant grows under nearly constant and mean conditions, for instance in diffused light, and in air moderately moist.

(4.) When a plant taken from mean conditions is exposed to dry air, transpiration is more rapid than absorption. It can reach a point at which the plant becomes irreparably injured.

(5.) When a plant taken from mean conditions is exposed to a saturated atmosphere, absorption is more rapid than transpiration, but in proportion as the want of water in the plant is supplied, the transpiration diminishes, and at last the plant is filled to repletion.

(6.) When a plant lacks water, the suction caused by transpira-

tion is not lost; it accumulates to act at once on the roots when water can be had. Then there is observed an absorption more energetic than the transpiration; the absorption diminishes as the want of water is supplied, and finally is governed wholly by the transpiration. G. L. G.

4. *On the causes of the abnormal shapes of plants grown in the dark.*—When deprived of light for a few days, growing plants which contain chlorophyll become etiolated, and undergo changes in form which are often very noticeable. The internodes extend to a greater length than when they grow in light, while the leaves develop only slightly and are often mis-shapen. From the fact that many plants provided beforehand with a store of nourishment, as in the case of corms and bulbs, produce in darkness, flowers of normal color and shape, but at the same time distorted and blanched leaves, the cause of the abnormal growth has been attributed by some to the disturbance in assimilation. Kraus has attributed the abnormal extension of internodes grown in the dark, to an excessive development of the pith and an imperfect development of fibrovascular tissue. He has also observed that the epidermal cells under such conditions have thinner walls than usual. Rauwenhoff, in Ann. Sci. Nat., ser. 6, 5, v. and vi. has reviewed the studies of Kraus and others, and comes to the following conclusions: The longer internodes have, in most instances a longer pith than the others, but that the growth of this cannot be the sole cause of the abnormal extension appears from the case of *Impatiens*, etc., where the pith is wanting. In darkness, the plants experimented upon developed in all parts an unusual amount of fundamental tissue, the tissue to which pith belongs. This abnormal development is attributed to the absence of the retarding influence of light, and to the action of negative geotropism. G. L. G.

5. *Cryptogamic Flora of Silesia: Algæ*, by Dr. Oscar Kirchner, Breslau, 1878.—This forms the first portion of the second volume of the Cryptogamic Flora of Silesia, published under the direction of Professor Ferdinand Cohn, of which the first volume has already been noticed in this Journal. The description of species is preceded by an account of the different works on the algæ of Silesia, and by an article on the general structure of algæ, especially of those growing in fresh water. The first notice of algæ in Silesia appears to be the description by Kundmann in 1736, of an "Oderhaut" or leathery mass growing on the Oder which was found by Gœppert, who examined Kundmann's specimens in 1840, to be formed of *Cladophora fracta*. Flotow, Gœppert, Ehrenberg, Cohn and Hilse have successively contributed to a knowledge of the flora and many of the original species were distributed in Rabenhorst's Algen Europas. On the whole, Dr. Kirchner thinks that less is known about the algæ than about the other cryptogamic groups of Silesia. The descriptive part of the work, embracing more than 250 pages, is well done, the author having been assisted by the notes of his instructor Professor Cohn. The *Florideæ* are treated first, and finally the

Schizosporeæ, the *Diatomes* preceding the latter order, contrary to the usual mode of arrangement. In classifying the *Diatomes* the author has followed Grunow and in the *Nostocs* he has adopted Thuret's classification. It is refreshing to see how the species of Kuetzing and others are united into more rational and comprehensible species. The second part of vol. ii, including the *Lichens* by Stein and the third volume including the *Fungi* by Dr. Schrœter, are announced for 1879. W. G. F.

6. *New York State Museum of Natural History, for the year* 1876: *Report of the Botanist*, CHARLES H. PECK; made to the Regents of the University, Jan., 1877. Published in Sept., 1878, in advance of the Report, pp. 78, and two plates of new *Fungi*.— This 30th annual report follows the 28th, the 29th being still in abeyance on account of some delay in the preparation of the plates. It appears that 168 species have during the year been added to the State Herbarium, of which 129 are Fungi, and 69 of these either new or previously undescribed. At the close of the report Mr. Peck adduces reasons for the opinion that *Lenzites Cookei* Berkl., *L. Cratægi*, *L. proxima*, possibly *L. Klotzschii*, *Dædalea confragosa*, and *Trametes rubescens*, are all forms of one species. A sad account is given of the ravages of a beetle, *Hylurgus rufipennis*, among the Spruces in the Adirondack region. W. G. F.

7. *Professor Eaton's Ferns of North America*, parts 8 and 9.— *Aspidium Lonchitis* and *Woodwardia angustifolia* make up an effective plate. Equally handsome and well executed is the next plate containing *Aspidium fragrans* and *Phegopteris alpestris*. The latter is one of the few subalpine species which are wanting in eastern North America and in the Rocky Mountains, but extend on the western side far down the Sierra Nevada, California. Among others, Sir J. D. Hooker collected it on Mt. Shasta. One would hope that its "fugitive indusium" might be fixed and the plant associated with *Athyrium Filix-fœmina*, which it resembles in habit. The next plate is devoted to delicate or pygmy subjects, *Trichomanes radicans* of Alabama, etc. (said to accord well with the original West Indian species even though the larger Irish *T. speciosum* may be different), and the lilliputian *T. Petersii*. The latter would have made a good show if a fair tuft had been depicted, in addition to the three or four frondlets. *Schizæa pusilla* (misspelled on the plate) is added, in a good figure, with faint and obscure analyses. An entire plate is well given to the Californian *Aspidium munitum*, of which the first figure represents a small form, and the second and third, varieties so peculiar that they would pass for distinct species. Three marked species of *Polypodium* fill the next plate, on which the noble *P. Scouleri* takes by an oversight the name of *P. vulgare*. It must be that the plate-proofs are not revised by the editor before lettering; as he would not let such slips pass. The last plate creditably represents two species of *Pellæa*, *P. andromedæfolia* of the western, and *P. flexuosa* of the southeastern portions of the United States, both extending into South America. A. G.

8. *Sarracenia purpurea*, with five naked rays in place of the umbrella to the style, an interesting monstrosity, was this year detected, near Grantville, Mass., by Mr. Isaac Sprague. The stigmas at the end of the rays are normal; but the branches radiating from the apex of the short style are distinct to the base, the nerve-form axis having merely a very narrow membranous border. A. G.

9. *Professor Alexander Agassiz's Zoological Laboratory at Newport, Rhode Island.*—Professor Agassiz gives the following account of his excellent laboratory in the Annual Report of the Curator of the Museum of Comparative Zoology for 1877–78.—Although summer instruction in Zoology has been abandoned at the museum, I have been able in my new laboratory at Newport to give facilities for work to half a dozen teachers (three ladies and three gentlemen); and it is my intention hereafter to divide the facilities at my command between students of the museum and teachers of our common schools, who must, however, be sufficiently advanced to study for themselves with profit.

The new Laboratory erected by me at Newport is twenty-five feet by forty-five. The six windows for work are on the north side, and extend from the ceiling to within eighteen inches of the floor. In the spaces between the windows and the corners of the building are eight work-tables, three feet by five, covered with white tiles, one foot of the outer edge being covered, however, with black tiles for greater facility in detecting minute animals on a black background. Between the windows, movable brackets with glass shelves are placed; while similar brackets extend across the windows and between the tables, thus providing a shelf at any desired height. The tables for microscope work are three-legged stands of varying height, adapted to the different kinds of microscopes in use. The whole of the northern side of the floor upon which the work-tables and microscope-stands are placed is supported upon brick piers and arches independent of the main brick walls of the building, which form at the same time the basement of the building. The rest of the floor is supported entirely upon the outside walls and upon columns with stretchers extending under the crown of the arches reaching to the northern wall. This gives to the microscopic work the great advantage of complete isolation from all disturbance caused by walking over the floor. This will be duly appreciated by those who have worked in a building with a wooden floor, where every step caused a cessation of work, and was sure to disturb any object just at the most interesting moment. * * * The water is taken some distance from the Laboratory, and drawn up at a horizontal distance of sixty feet from the shore in a depth of some four fathoms, the end of the suction pipe standing up vertically from the ground a height of five feet, and terminating in an elbow to prevent its becoming choked. The water is led through iron pipes coated inside with enamel. From the tank, the salt water is distributed in pipes extending in a double row over the central tables, over the long narrow tables for aquaria, and along the whole length of the glass shelves on the south wall. Large faucets to draw off salt water

are placed at each sink; and by a proper arrangement of valves it is possible to lead fresh water to a part of the pipes, in case it is needed. The pipes leading over the tables and shelves are provided with globe valves and nozzles, to which rubber pipe can be attached and the water led to a vessel below: there are fifty such taps, each of which can supply water or air to at least three or four jars. The overflow runs into gutters laid alongside the tables, leading into the main drain pipe. To aerate the salt water, I use an injector invented by Professor Richards of the Institute of Technology. This can be used to supply aerated water directly to the jar by providing it with a siphon overflow, or the aerated water can be collected in a receiver, from which air alone is then led to the jar. This latter course is the only practical one for delicate specimens, and for the bulk of the work of raising embryos. The east and west sides have large windows and doors provided with blinds; they always remain open, with the blinds closed to keep out sun-light, and serve to ventilate the Laboratory thoroughly. Large tables for dissection, covered with slate and adjoining a sink provided with fresh and salt water, are placed across the windows of these sides.

Ever since the closing of the school at Penikese, it has been my hope to replace, at least in a somewhat different direction, the work which might have been carried on there. It was impossible for me to establish a school on so large a scale; but I hope, by giving facilities each year to a few advanced students from the Museum and teachers in our public schools, to prepare, little by little, a small number of teachers, who will have had opportunities for pursuing their studies hitherto unattainable. The material to be obtained at Newport is abundant. The dredging is fair, and not difficult, as the depth in the immediate neighborhood does not exceed twenty to thirty fathoms. The pelagic fauna, however, is the most abundant. During the course of each summer, by the use of the dip-net, representatives of all the more interesting marine forms are sure to be found. With my small steam launch, a large space can always be traversed any evening, and advantage taken of the condition of the wind and tide, the launch being amply large for easy dredging in the moderate depths of the entrance of Narragansett Bay. The Laboratory is placed on a point at the entrance of Newport Harbor, past which sweeps the body of water brought by each tide into Narragansett Bay, and carrying with it every thing which the prevailing southwesterly winds drive before it. Newport Island and the neighboring shores form the only rocky district in the long stretch of sandy beaches extending southward from Cape Cod,—an oasis, as it were, for the abundant development of marine life along its shores.

V. Miscellaneous Scientific Intelligence.

1. *Report on the Arid Region of the United States; with a more detailed account of the lands of Utah;* by J. W. Powell.

196 pp. 4to. With Maps. Ex. Doc., No. 73. Made under the direction of the Interior Department. Washington, 1878.—Prof. Powell here gives an excellent general account of the features, climate and drainage of the great region, describes its agricultural, pasturage and timber lands, and discusses its methods of water supply, and important subjects connected with irrigation. The report also presents a detailed description of the irrigable lands of the various basins, and their present condition, and treats of the government land system needed for the arid region. Mr. Powell's many expeditions over the Rocky Mountain region, under Government auspices, have made him familiar with the country described, and have well fitted him for the preparation of such a work.

2. *United States Geological Exploration of the Fortieth Parallel*, CLARENCE KING, geologist in charge. Systematic geology, by CLARENCE KING. 804 pp. 4to, with 28 plates and 12 analytical geological maps, and accompanied by a geological map and topographical atlas. Submitted to the Chief of Engineers, and published by order of the Secretary of War, under authority of Congress.—We have barely space at this time to announce the publication of this large and very valuable volume on the geology of Western America, by Mr. Clarence King, which closes the author's Rocky Mountain exploration of the Fortieth Parallel.

3. *Annual Report of the Board of Regents of the Smithsonian Institution for the year* 1877. 500 pp. 8vo. Washington, 1878.

4. *The late Professor Henry.*—The family of the late Professor Henry ask to be entrusted with such letters of his, or other MSS. papers, now in the possession of any of his correspondents, as may be of use or interest in the preparation of a memoir of his life. Such letters may be sent to *Mrs. Henry*, care of the Secretary of the Smithsonian Institution, Washington. They will be gratefully received, carefully preserved, and, when desired, duly returned to the owner.

Anales de la Sociedad Cientifica Argentina, entrega ii. Tomo vi. Agoste de 1878. Buenos Aires, 1878.

Report of the Meteorological Service of the Dominion of Canada for the year ending Dec. 31, 1877; by the Superintendent. Ottawa, 1878.

Monographie der Phaneropteriden, von C. Brunner von Wattenwyl; herausgegeben von der k. k. zoologisch-botanischen Gesellschaft in Wien. 401 pp. 8vo. Vienna, 1878.

Science News. Published fortnightly, by S. E. Cassino, at Salem, Mass. First number appeared in November. $2 a year.

Science Observer, Boston. Vol. II. No. 3, appeared in October.

Anales del Ministerio de Fomento de la República Mexicana. Vol. III. November to December, 1877. This volume is largely occupied with the meteorological bulletin of the Central Observatory of Mexico.

Contributions to Paleontology, No. 2, by S. A. Miller and C. B. Dyer, July 22, 1878. Contains descriptions of several new species from the Cincinnati group.

The Paleontologist, by N. P. James, No. 2. Cincinnati, Sept. 14, 1878. Contains notices of Silurian fossils of Ohio.

OBITUARY.

M. DELAFOSSE, Professor of Mineralogy in the Paris Museum of Natural History and the Faculty of Science, died on the 13th of October last.

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